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Big Sky Dam,
Madison County,
Montana, MT-1395

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- INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

BIG SKY DAM
MADISON COUNTY, MONTANA
MT - 1395

PREPARED FOR:

HONORABLE TED SCHWINDEN
GOVERNOR, STATE OF MONTANA

AND

BIG SKY OF MONTANA, INC.
OWNER / OPERATOR

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PREPARED BY:

Christian, Spring, Sielbach & Associates
Bozeman, Montana

Assisted By:

Northern Testing Labs, Inc.
Great Falls, Montana

March 1981

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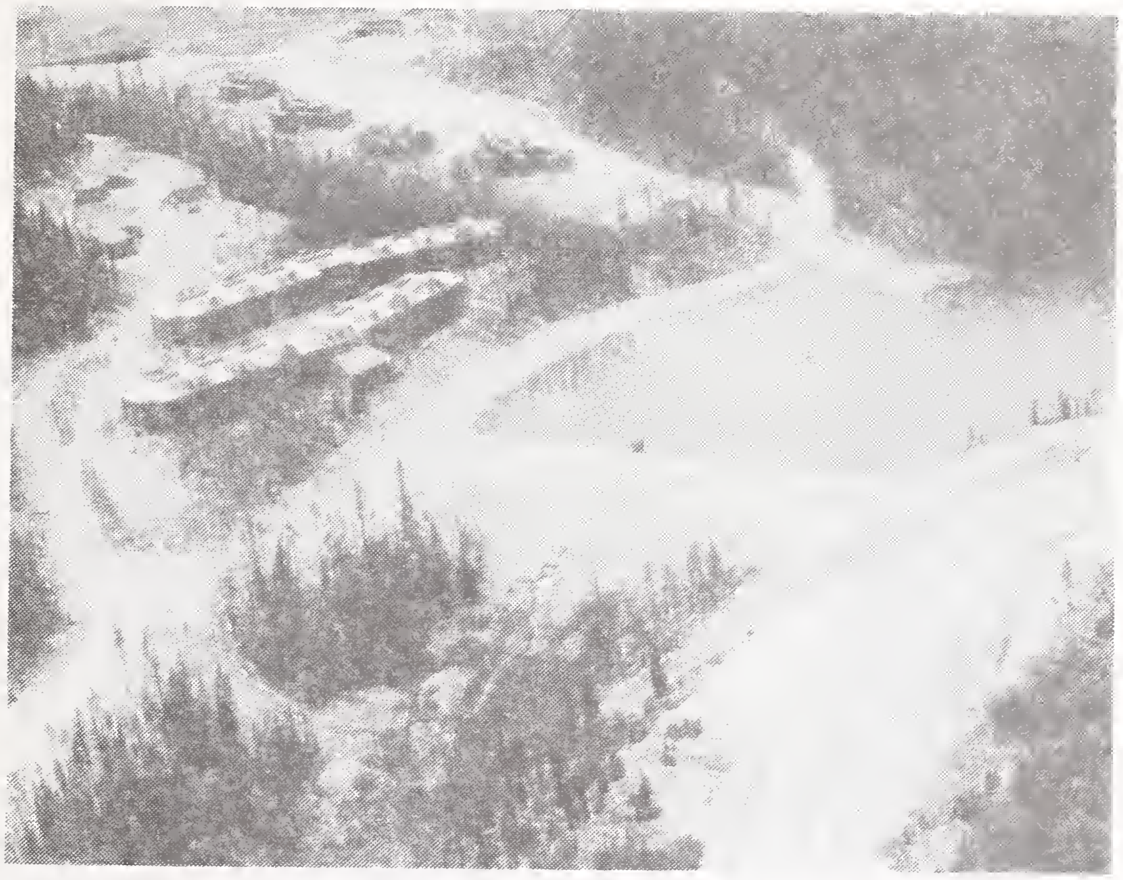

Aerial Photo of Big Sky Dam

Note: Resort at top left and Emergency Spillway at right

Aerial Photo of Big Sky

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EXECUTIVE SUMMARY

Personnel of Christian, Spring, Sielbach & Associates, principal contractor, and Northern Testing Laboratories, Inc., subcontractor, under a contract with the Montana Department of Natural Resources and Conservation (MDNRC) and with representation from Big Sky of Montana, Inc., and the MDNRC, inspected Big Sky Dam on 20 June, 1980, under the authority of Public Law 92-367. The project is located in the NW ¼ of Section 29 and the NE ¼ of Section 30, Township 6 South, Range 3 East, M.P.M., on the Middle Fork of the West Fork of the Gallatin River near the boundaries of Madison and Gallatin Counties, Montana, about 50 miles southwest of the City of Bozeman, Montana (Plate 1). The dam crest serves as a roadway to the Big Sky Mountain Village located at the foot of Lone Mountain about .5 miles southwest of the dam site.

This report was compiled from information obtained during the onsite inspection, review of preliminary design data, construction plans, drill explorations and analysis of available hydrologic information. Findings were compared with engineering criteria that are currently accepted by most private and public agencies engaged in dam design, construction, and operation.

Findings and Evaluations

Big Sky Dam was constructed in 1972-1973 by Big Sky of Montana, Inc., with engineering design services provided by Morrison & Maierle. The dam is owned and operated by Big Sky of Montana, Inc. The project was planned as a recreation and fish and wildlife storage facility.

The 52-foot high dam impounds 225 acre-feet of water at top of dam elevation 7429.0 feet NGVD. The principal spillway is an uncontrolled 4-foot square concrete drop inlet with crest elevation at 7420.0 feet NGVD. An earth emergency spillway with crest elevation 7426.0 feet NGVD and a control crest length of 80 feet provides for passage of flood flows. There is approximately 112 acre-feet of surcharge storage available between the principal spillway crest and top of dam. On the basis of criteria in the

U.S. Army Corps of Engineers' Recommended Guidelines for Safety Inspection of Dams (Ref. 1), the project is intermediate in size. The sudden failure of Big Sky Dam would cause extensive property damage and could endanger lives of downstream residents and recreationists. The conclusions on probable damage are based on the field visit and judgment. No dam breach analysis or routing of a dam break hydrograph was made for the downstream area.

The project is classified as having a high (Category 1) downstream hazard poential. Inspection criteria (Ref. 1) recommend that an intermediate sized project with a high downstream hazard potential be capable of safely handling the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

The estimated PMF for the 5.3 square mile drainage basin, (developed for this dam safety study), resulted from a general storm PMP. The resultant PMF has an estimated volume of 4700 acre-feet and a peak flow of 24,650 cubic feet per second (cfs). The combined maximum discharge capacity of the principal and emergency spillways with the reservoir at dam crest elevation 7429.0 feet NGVD is 1330 c.f.s. Routing of the estimated PMF developed for safety evaluation of Big Sky Dam indicates that the dam is overtopped when approximately 19% of the total flood volume enters the reservoir. Routings of lesser hypothetical floods made by applying percentages to the PMF ordinates showed that a flood corresponding to 10% PMF ordinates is just controlled by the project. Larger floods would overtop the dam. The dam is constructed of materials that would readily erode and failure is likely to occur when overtopped with flood waters.

The emergency spillway for this project is excavated in natural ground on the left or north abutment. The emergency spillway exit channel passes through a 108-inch-diameter corrugated metal pipe (CMP) and exits on a steep slope near the downstream toe of the dam. At the time of inspection the CMP was obstructed with shoring, bracing, and two conduits for water and sewer. (The shoring and bracing have subsequently been

removed.) The unlined exit channel is composed of materials that would quickly erode. Any flood event that would cause flow in the emergency spillway could threaten the integrity of the CMP and the abutment of the dam.

The visual inspection of the embankment revealed no serious cracks, irregularities, or slumps. However, numerous seeps were noted in the downstream slope below pool elevation, at the toe of the dam, and at the abutment contacts. Some minor erosion at seepage exit points and in the downstream trough at abutment contacts was noted. Although the construction plans prepared by Morrison and Maierle provided for installation of internal drainage, the outlet pipe could not be located and the drain's existence could not be verified. No records of stability analysis or evaluation of the seismic response of the dam were available for our review. Based on field observations of significant seepage indicating a very high phreatic surface in the dam and with the potential for erosion and sloughing of the downstream slope and emergency spillway, it is our judgment that the embankment is marginally stable at best and immediate corrective action is needed.

Because: (1) the project is incapable of controlling one-half the PMF without overtopping and causing the dam to fail, (2) significant seepage exists at high elevations in the downstream embankment, and (3) the exit channel of the earth emergency spillway has a high potential for erosion and possible failure, Big Sky Dam is considered unsafe, non-emergency until recommended actions are completed. A letter from CSSA to MDNRC sets forth conditions found in the inspection requiring immediate attention. A letter from MDNRC to Big Sky advises of urgency of correcting deficiencies. Copies of these letters are appended to this report.

The low level outlet and principal spillway could not be inspected during the site visit because of reservoir water surface elevation. No downstream warning system is in effect.

Recommendations

Due to storage between normal pool and dam crest, the present project provides a small degree of flood protection to the downstream area. The intent of the report recommendations is to maintain or improve project safety without decreasing this existing flood protection. A downstream warning plan for use in the event of impending dam failure must be developed, tested and placed in action. Develop and implement plans to modify the emergency spillway to provide for safe passage of anticipated flood flows. Inspect the inside of the outlet works control tower, combined principal spillway and low level outlet conduit, and control gates and repair as required. Repair gate stem and guide bracket. Repair eroded areas around the wingwalls of impact basin. Immediately install piezometers and monitor to determine the phreatic surface and pore pressure distributions within the embankment. Evaluate seepage and provide necessary measures for seepage control. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity. Conduct engineering studies including field exploration and laboratory testing of foundation and embankment soil materials, to evaluate embankment stability. Modify the dam embankment and spillway capabilities to provide for safe passage of the spillway design flood (SDF) as studies indicate. Conduct periodic inspections of the project at frequent intervals for the next 2 years and at 5-year intervals thereafter by engineers experienced in earth dam design, construction, operation, and maintenance. Develop and implement an operation and maintenance plan for the project. Remove sewer and water lines from emergency spillway and protect dam from erosion in case pipes break. Prior to performing engineering studies, coordinate the work with the State of Montana Department of Natural Resources and Conservation to insure compliance with all pertinent laws and regulations.

Bob B. Gemmell
Professional Engineer
Montana 504 E.

Bob B. Gemmell

PERTINENT DATA

1. General

Federal ID No.	MT-1395
Owner/Operator	Big Sky of Montana, Inc.
Date Constructed	1973
Purpose	Recreation
Location	N½ Sections 29 & 30, T6S, R3E MPM
County, State	Madison, Montana
USGS Quadrangle	Spanish Peaks, Montana
Watershed	Middle Fork of West Fork of Gallatin River
Downstream Hazard Potential	Category 1, High
Size Classification	Intermediate

2. Reservoir

Normal Pool Elevation (Principal Spillway Crest)	7420.0 ft. NGVD
Surface Area at Normal Pool	9.8 acres
Drainage Area	5.3 square miles
Storage at Normal Pool (Principal Spillway Crest)	113 acre-feet
Storage at Emergency Spillway Crest	188 acre-feet
Storage at Dam Crest	225 acre-feet
Surcharge Storage	112 acre-feet

3. Emergency Spillway

Type	Uncontrolled, unlined earth with culvert through dam abutment
Crest Elevation	7426.0 feet NGVD
Crest Length (control section)	80 feet
Capacity with Reservoir at Dam Crest	915 c.f.s.
Culvert	108 inch diameter by 75 feet long CMP

PERTINENT DATA

Continued

4. Principal Spillway

Type	Uncontrolled concrete drop inlet with trash rack
Crest Elevation	7420.0 feet NGVD
Crest Dimensions	4 foot by 4 foot
Riser Type	Reinforced concrete - 4 ft. X 4 ft.
Riser Height	34.5 feet
Outlet Conduit	48 inch RCP
Conduit Length	160 feet
Capacity with Reservoir at Dam Crest	416 c.f.s.

5. Outlet Works

Description	RCP conduit, gated at spillway riser, discharges into bottom of principal spillway riser
Conduit Type	36 inch RCP
Conduit Length	60 feet
Gates	Two-30 in. X 30 in. sluice gates in tandem
Capacity with Reservoir at Emergency Spillway Crest	200 c.f.s. (normally closed)

6. Dam

Type	Rolled earth fill
Crest Elevation	7429.0 feet NGVD
Crest Length	400 feet
Crest Width	40 feet
Hydraulic Height (crest to toe)	52 feet
Upstream Slope	1V on 2.5H
Downstream Slope	1V on 2H

CHAPTER 1
BACKGROUND

1.1 INTRODUCTION

1.1.2 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the Big Sky Dam, owned by Big Sky of Montana, Inc..

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers to conduct safety inspections on non-federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' Report to the United States Congress on "National Program of Inspection of Dams" in May, 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary the guidelines recommend a two-phase study procedure for investigation and evaluation of existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam.
(2) based upon an evaluation of the available data and a visual inspection.
(3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted.
(4) not intended to include extensive explorations, analysis or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analysis.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work.

Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and action or failure to act under this act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership and operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify current physical and operational conditions of the dam and appurtenances; and to determine if emergency measures and/or additional studies, investigations, and analyses are needed, so that corrections can be made in a timely manner by non-federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on a review of available engineering data and records, construction drawings of Big Sky Dam, and a visual inspection of the project. Engineering data and records, including preliminary hydrologic and hydraulic studies were obtained from the office of Morrison and Maierle in Helena, Montana. Morrison and Maierle provided engineering design services for the project. Construction inspection was the responsibility of the owner. Inspection procedures and criteria used for this report were those established by the Recommended Guidelines for the Safety Inspection of Dams (Ref. 1).

The inspection was conducted jointly by personnel from Christian, Spring, Sielbach & Associates and Northern Testing Laboratories, Inc., subcontractors. Personnel who participated in the field inspection and contributed to this report were:

CSSA- Bob B. Gemmell, Engineer, Team Leader
Alfred Cunningham, Hydraulics/Hydrology (report only)
Les Crawford, Civil Engineer

NTL- Robert Gillespie, Geotechnical Engineer
Bill Henning, Geologist
Gary Quinn, Geotechnical Engineer

MDNRC - Montana Department of Natural Resources and Conservation
Art Taylor, Dam Safety Engineer

Other personnel present and participating in the field inspection include:

Ray Tout, Big Sky of Montana, Inc., Maintenance Supervisor

This report has been reviewed by: Big Sky of Montana, Inc. and the State of Montana and their written comments are enclosed in Appendix A.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

a. Location, Owner, and Purpose.

Big Sky Dam is located on the Middle Fork of the West Fork of the Gallatin River in the north one-half of Sections 29 & 30, Township 6 South, Range 3 East, M.P.M., in Madison County, Montana, approximately 50 miles southwest of Bozeman, Montana by road. (Plate 1). The National Dam Inventory designates the dam as MT 1395, and lists it as having a high (Category 1) downstream hazard potential in case of failure.

The dam is owned, operated and maintained by Big Sky of Montana, Inc. a resort development corporation. The project was planned as a recreation, and fish and wildlife storage facility in conjunction with the Big Sky recreation-resort area.

b. Description of Dam and Appurtenances.

Big Sky Dam is a rolled earth-fill structure with a hydraulic height of 52 feet and a crest length of about 400 feet (Plate 3). It has a combined uncontrolled principal spillway and controlled outlet works with a common outlet conduit. A three chambered monolithic riser and gate control tower is located in the reservoir about 50 feet upstream from the dam axis (Plate 6). An uncontrolled, unlined earth emergency spillway is located on the left or north abutment. The emergency spillway passes through the left abutment via a 108-inch-diameter CMP which serves as a bridge for the road on the dam crest. The pipe is pierced by water and sewer mains. The dam impounds approximately 225 acre-feet at dam crest elevation 7429.0 feet NGVD which is 3 feet above emergency spillway crest elevation 7426.0 feet NGVD, and approximately 113 acre-feet at principal spillway crest (normal pool) elevation 7420.0 feet NGVD. The contributing drainage area is 5.3 square miles.

A principal road to the Big Sky Ski Resort and the Mountain Village Condominium area crosses the dam crest.

c. Hazard Potential

Based on visual reconnaisance and engineering judgement, Big Sky Dam is located such that a sudden breach could endanger many lives and cause extensive property damage in the downstream area. Several residences and condominiums in the Lower Meadow Village, about four (4) miles downstream, a ski lift base area and sewage lagoon about 3/4 miles downstream would be affected. Primary access to the Big Sky Mountain Village Ski Resort area would be cut off.

On the basis of the recommended inspection guidelines, Big Sky Dam's size is intermediate and the downstream hazard potential is high (Category 1). The conclusions on probable damage are not supported with a dam breach analysis to determine possible flood heights that would be experienced in the areas downstream that could be affected by a sudden failure. A more detailed hydrologic and hydraulic routing study is recommended to accurately determine the downstream hazard potential.

1.2.2 Regional Geology

The foothills and mountains in this region are largely underlain by gneiss and schist of Archean type, overlapped by folded and faulted Paleozoic and Mesozic sedimentary rocks. Narrow northwest-trending belts of these sedimentary rocks lie within these metamorphic rocks. These belts are bounded largely on the northeast by steep faults. Intruded into these rocks are granitic rocks of the Idaho and Boulder batholiths and outlying intrusives. Tertiary volcanic rocks overlie old eroded surfaces in many places, particularly in and near Yellowstone National Park. The volcanic rocks range in age from Eocene to upper Miocene and later, and have undergone uplift, some deformation, and faulting in the orogenic movements that produced the mountain ranges. During the Wisconsin and earlier stages of glaciation, there was probably an extensive ice cap covering most, possibly all of the Yellowstone Park Plateau and Absaroka Range and Beartooth Mountains to the north and northeast. Farther north, northwest, and west, between the Park and the Idaho-Montana state line, there were many local glaciers, some of them large, heading in the cirques that scallop the upper slopes of the highest mountain ranges both eastward and west of the divide. During Wisconsin and post-Wisconsin time, numerous gravelly terraces were deposited, possibly marking minor substages of cutting downward and incipient lateral planation. Some of the terrace gravels may be composed of outwash from mountain glaciers. (Reference 2)

1.2.3 Seismicity

The Madison Range lies in an area of generally major seismic activity. For a recurrence interval of 50 years and a "never exceed" probability of 0.90, earthquakes of Richter Magnitude of 6.5 to 7.5 are anticipated. Associated bedrock accelerations ranging from 0.2 to 0.4g could be expected. Ground accelerations in the very dense, relatively shallow foundation soils would be similar to those in bedrock. Corps of Engineers' guidelines recommend a seismic coefficient of 0.10 for zone 3. (Reference 1) Major recorded seismic events surround the damsite. These events are associated with the numerous active faults in the area. A major fault, the Madison Range fault, is approximately 12-15 miles directly west of the dam. The fault is a high angle normal fault with the west side downthrown. The latest movement on most of the fault is late Quaternary in age.

1.2.4 Site Geology

A preconstruction subsurface investigation consisting of drill holes and test pits was made of this area by Northern Testing Laboratories, Inc. The report on subsurface investigation, along with a visual examination of the area, was used to prepare the following site description. The dam was constructed in a relatively narrow channel, formed by downcutting of the creek through glacial moraine and outwash plain deposits consisting of clay to cobble size material. Scattered silt and clay pockets are interbedded, but are not continuous for any great distance. The glacial and alluvial soils extend to a depth of approximately 70 feet on the abutments, and from 5 to 40 feet in the stream channel. Underlying these deposits is shale, sandstone, and claystone bedrock of the Colorado Group. Bedrock rises to form a small knoll just upstream of and partially under the north or left abutment. This rock knoll is covered by 5 to 10 feet of overburden. Both abutments along with the major part of the dam are tied to the glacial deposits. The outlet conduit and emergency spillway are resting on the glacial and alluvial deposits. Borings are located on the foundation profile, Plate 5.

1.2.5 Design and Construction History

The project was originally designed by Thomas, Dean and Hoskins (TDH), Great Falls, Montana in the early 1970's. Hydrology as well as soil and site conditions were investigated. Original hydrology was performed by Prof. Ted T. Williams, Bozeman, Montana, using historical precipitation and runoff data of several drainages in the immediate area. Original soil and foundation investigation was performed by Northern Testing Laboratories, Great Falls, Montana using their own borings and field inspections.

About 1972 Morrison and Maierle (M & M), Helena, Montana replaced TDH as the Big Sky Inc., development engineers, and completed the design of the dam and appurtenances. Construction drawings, and preliminary design data were made available to the inspection team for review. No "as built" plans as such are available, and for this reason, installation details and location of core trench, foundation drainage, and other buried appurtenances is unverified.

The project was constructed in 1972 and 1973, with the owner providing construction supervision and observation with their own forces. No repair, inspection, or post-construction problem history was available for review.

CHAPTER 2
INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Outlet/Principal Spillway

The low level outlet works and the principal spillway for Big Sky Dam are combined into a single structure located near the right abutment of the dam (Plate 4). The uncontrolled principal spillway riser and gate control tower is a three cell monolithic concrete structure located about 50 feet upstream from the central axis of the dam (Plate 6). A 48-inch-diameter reinforced concrete pipe extends 160 feet through the embankment and terminates in an impact type energy dissipator at the downstream toe of the dam. The low-level outlet is a 36-inch-diameter reinforced concrete pipe which extends 55 feet from the reservoir intake to the control tower. The design slope of the 36-inch-diameter conduit is 0.050 and the design slope of the 48-inch-diameter outlet conduit is 0.053. The uncontrolled principal spillway riser is the downstream chamber in the control tower and has four foot square inside dimensions. The crest elevation of the principal spillway riser is at 7420.0 feet NGVD, and design elevation of the base of the riser is 7385.5, providing a riser height of 34.5 feet. The two upstream chambers of the control tower are wet wells and each has a 30-inch-square sluice gate located on the downstream side at the base of the control tower. The center chamber acts as a principal spillway when the downstream gate is in open position. A structural steel trash rack covers the entire top of the control tower and principal spillway riser (see Plate 6). A structural steel platform on top of the trash rack serves as a base for the gate hoist mechanisms (Photo 7).

Water surface in the reservoir at time of inspection was about one foot above the principal spillway crest. This prevented complete inspection of the control tower, principal spillway, and conduit. Visible concrete appeared in good condition in the outlet energy dissipator. There appeared to be some spalling of concrete surfaces at the inside top of the principal spillway riser. A small mesh (½ inch) wire screen that had been placed around the outside of the structural steel trash rack was partially plugged with debris and was restricting flow in the principal spillway riser. With the screen removed, the vertical trash rack is still susceptible to clogging with debris. The upstream gate on the lower level outlet was in a closed position. One gate stem guide had broken at a weld and the stem was bent just below the threads. Gate stems were not encased in protective pipe (Photo 8). No attempt was made to operate either gate, due to apparent problems. Some erosion has taken place behind the wing walls at the energy dissipator outlet, however, there is no evidence of deep scour downstream that would threaten to undermine the structure (Photo 9). Seepage near the right or south corner of the impact basin has caused minor sloughing. It was impossible to determine if the source was through the foundation, along the discharge conduit, or possibly a buried toe drain outlet (Photo 10).

The discharge rating of the uncontrolled principal spillway was developed with the sluice gate controlling the low level outlet in a closed or normal position, and the downstream gate in open position. Although the vertical trash rack is susceptible to plugging, the net opening between

structural members was computed in assessing weir flow over the crest of the riser. The wire mesh present at the time of inspection was considered removed. A discharge coefficient of 3.1 was used in developing the weir head-discharge relationship for the top of the principal spillway riser and center chamber of control tower. Energy losses in the 48-inch-diameter outlet conduit were accounted for by using a Manning's "n" of 0.012 for full conduit flow. When reservoir elevations are above elevation 7427.0 feet NGVD, or approximately 7 feet above the principal spillway crest, full pipe flow in the outlet conduit controls. The maximum discharge of the principal spillway, with the above conditions, and with the reservoir at emergency spillway crest elevation 7426.0 feet NGVD, was estimated to be 380 c.f.s. and 416 c.f.s. with reservoir at dam crest elevation 7429.0 feet NGVD. The principal spillway rating curve is shown on Plate 9.

2.1.2 Emergency Spillway

The side discharge emergency spillway is excavated in natural ground just upstream from the left abutment where it drops into an excavated outlet channel (Photos 12 and 13 and Plate 7). The outlet channel passes through a 75 foot long, 108-inch-diameter corrugated metal pipe, that serves as a bridge for the roadway on the crest of the dam, then into a steep gradient exit channel. (Plate 8). The control crest on the emergency spillway between the reservoir and the outlet channel is excavated in natural ground, is trapezoidal in shape with a bottom width (crest length) of 80 feet and side slopes of 1V (vertical) on 10 to 20H (horizontal). The crest elevation is 7426.0 feet NGVD.

The 10 foot deep exit channel is somewhat "U" shaped with a bottom width of 10 feet and side slopes of 1V on 2H. The 108-inch-diameter conduit is pierced by a water main that parallels the upstream shoulder of the dam, and a sewer main that parallels the downstream shoulder of the dam. Settlement around the culvert has caused some bulges and loss of circular shape (Photos 14 and 15). Wood timbers used for shoring and bracing were in place at time of inspection. These would present a serious potential for clogging and obstructing flow in the event of emergency spillway operation. The emergency spillway is almost barren of grasses and vegetation except for a few very young trees at spillway crest (Photos 11 and 12). There is no evidence that there has been flow in the emergency spillway. The exit channel upstream from the culvert, has water seeping through the channel sides and bottom at about 1 to 2 GPM. The exit channel immediately downstream from the culvert has a steep gradient and the sides and bottom are composed of non-cohesive sand silts and gravels (Photo 16). The material appears to be highly erodable with small flows. High flows could undermine the road culvert at the downstream end and endanger the dam.

Emergency spillway discharge capacity was computed by assuming critical depth at the downstream point where the spillway slope abruptly changes and obviously exceeds critical slope (Plate 8). Backwater computations were made in the approach channel with a Manning's "n" of 0.030. The maximum discharge capacity of the emergency spillway with the reservoir at dam crest elevation 7429.0 feet NGVD was estimated to be 915 c.f.s. The combined capacity of the emergency and principal spillways with reservoir at elevation 7429.0 feet was estimated to be 1330 c.f.s. (Plate 10). Control remains at the emergency spillway crest elevation

7426.0 feet NGVD, until water levels are within inches of dam crest elevation 7429.0, at that point control is transferred to the entrance of the 108" CMP as the pipe becomes submerged.

2.1.3 Freeboard

Routings indicate that the dam overtops during the probable maximum flood (PMF; see Paragraph 2.2.4), therefore freeboard does not exist with the recommended spillway design flood. At the time of inspection the reservoir was at an elevation approximately 1 foot above the principal spillway crest elevation of 7420.0 feet NGVD. The vertical distance between the low point on dam crest and reservoir level at time of inspection was approximately 8 feet. The highest historical lake levels appear to be at elevation 7422.0 feet NGVD, 7 feet below the top of the dam. Although the dam overtops during the PMF, wind-generated waves are not expected to overtop the dam during normal operation with reservoir elevation at or below the principal spillway crest. The maximum fetch is about 800 feet for the reservoir and wave runup on the embankment is expected to be less than 2 feet.

2.2 HYDROLOGY

2.2.1 Physiography and Climatology

The Big Sky reservoir site is located on the Middle Fork of the West Fork of the Gallatin River in Southwestern Montana. Latitude 45° 17.2', longitude 111° 23.5. The drainage basin is located in steep, alpine terrain, drains northwest to southeast and is roughly triangular in shape (Plate 2). The total contributing drainage area is 5.3 square miles with a main water course about 3 miles in length. Three tributaries drain into the reservoir which has a surface area of 9.8 acres at normal pool.

Climate for this region is classified as "continental" (Ref. 3) with cold winters and brief, mild summers. Average frost-free season for the site is approximately 60 days (Ref. 3). Average annual precipitation is 40 inches most of which falls as snow. Summer weather patterns cause a flow of unstable air in the state which results in several types of severe storms including numerous thunderstorms. Average annual potential evapotranspiration is about 13 inches for the Big Sky drainage basin while average annual lake evaporation for this region is about 35 inches. Air temperatures range from 85°F in summer to -40°F in winter.

2.2.2 Reservoir Storage and Spillway Discharge

The Big Sky reservoir has a storage capacity of 113 acre-feet at principal spillway crest, elevation 7420.0 feet NGVD and 225 acre-feet at top of dam, elevation 7429.0 feet NGVD, providing approximately 112 acre-feet of surcharge storage. The combined discharge of the principal spillway and emergency spillway with the reservoir at dam crest is about 1330 c.f.s.

2.2.3 Estimated Probable Maximum Flood (PMF)

The probable maximum flood (PMF) is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

The PMF for Big Sky Reservoir was developed using the HEC-1 Flood Hydrograph - Dam Safety Investigation Computer Program (Ref. 4). Primary program input consisted of the 72-hour probable maximum precipitation (PMP) which was obtained for the study site from Ref. 8. The 24 hour 10-square mile PMP was determined to be 13.0 inches. Subsequent adjustments based on area location resulted in a 72-hour PMP for Big Sky reservoir of 16.25 inches with a maximum hourly value of 5.75 inches.

The PMF hydrograph was developed based on a 10 minute unit hydrograph (UHG) constructed using procedures outlined in Ref. 6. In calibrating the SCS unit hydrograph for input to HEC-1 a basin time of concentration of 0.6 hours and a basin area of 5.3 square miles were used. It was assumed that frozen soil conditions prevailed during the PMP resulting in an infiltration rate of zero.

The resulting estimated PMF peak inflow to Big Sky Reservoir was found to be 24,650 cfs with a 6-hour inflow volume of 2850 acre-feet. The 72-hour inflow volume was 4700 acre feet.

2.2.4 Flood Routing

Routing of the estimated PMF hydrograph developed for this study through Big Sky Reservoir was accomplished by means of the computer program, HEC-1. (Ref. 4). Initial reservoir inflow was assumed to be zero. Initial water surface elevation was assumed to be at principal spillway crest elevation 7420.0 feet NGVD at the onset of the PMF. Routing was accomplished using the modified puls method. Routings were made of lesser hypothetical floods to determine the magnitude of floods the dam can contain. The hypothetical hydrographs were obtained by applying percentages to the PMF ordinates.

Routing studies indicate that:

a. During the full PMF the dam would be overtopped when approximately 19 percent of the total flood volume enters the reservoir.

b. A flood with a hydrograph corresponding to 10 percent PMF ordinates is just controlled by the project. Larger floods would overtop the dam.

2.3 GEOTECHNICAL EVALUATION

The Mountain Village Dam was constructed by Big Sky of Montana, Inc., beginning in the fall of 1972, and was completed during 1973. A preliminary investigation was conducted by Northern Testing Laboratories, Inc. for the project consultants in 1972 (Ref. 7). The investigation was limited to describing foundation materials, evaluating adjacent borrow sources, prescribing embankment material gradations, plus recommending general site preparation techniques and density requirements. This investigation did not include recommendations for or review of the dam design.

The final drawings prepared by the consultant were made available for our use in this evaluation. As-built plans or records were not available.

2.3.1 Dam Embankment

The dam embankment was designed as a homogeneous section with a cutoff trench and toe drain. Initial design concepts apparently included a

central core section, but that concept was abandoned prior to final plan preparation.

The embankment has a maximum height of 52 feet, with a 22 feet wide crest accommodating a gravel surfaced roadway. Two 8-foot-wide gravel shoulders are provided along the roadway for safety purposes. The upstream slope is approximately at the plan slope of 1V on 2.5H. The downstream slope is somewhat irregular, with a maximum 1V on 2H slope extending from the embankment crest to an elevation 33 feet below the crest, with gradual slope flattening thereafter. Design downstream slope was 1V on 2H. A cross section, plan, and profile of the dam embankment is shown on Plates 3, 4 and 5.

Embankment materials were apparently borrowed from the left abutment area and consisted of the glacial moraine and till soils, similar to those observed in the cut slopes. These soils were described in the borrow material investigation as a well-graded mixture of gravel and sand with varying amounts of silt and clay. Gradation recommendations called for removal of 3-inch plus material for any core trench and central core construction. Remaining embankment materials were to meet the following gradation:

Sieve Size	Percent by Weight Passing
No. 4	50-80
No. 200	15+

Internal drain and filter materials were to be a sandy gravel with some silt, and were to be taken from a borrow area near the right abutment. Materials comprising the toe drainage system were shown on construction plans as pervious filter material protecting a 3-inch to 3/4-inch trench backfill material. Specified slope protection was riprap with a filter blanket upstream and topsoil downstream.

The upstream slope could not be inspected because the pool level was one foot higher than the normal operating level. Vegetation was very sparce and no riprap slope protection was evident, (Photo 1). Minor irregularities in the slope near the crest were due to normal roadway-shoulder maintenance. No evidence of instability or serious erosion was observed on the upstream slope.

Numerous seeps were noted in the downstream slope below pool elevation. Minor sloughing, occasionally accompanied by seepage, contributed to general slope irregularity. Vegetative growth consisting of grasses was supported only at seepage locations. No evidence of topsoil was observed (Photos 2, 5 and 6).

Both abutment areas showed evidence of seepage at the contacts. Loose, miscellaneous fill has been dumped over the downstream right abutment. Instability of this fill is apparent, (Photo 3 and 4). There is minor erosion due to runoff channelization at the downstream left abutment contact.

Water and sewer lines have been constructed in the upper part of the embankment, from abutment to abutment. The depths of these trenches are not known but they are assumed to be about 5 to 8 feet deep.

No monitoring devices were installed during or since dam construction.

2.3.2 Foundation Conditions, Seepage, and Drainage

The dam is placed across a narrow creek channel cut through glacial moraine and outwash plain deposits. The glacial deposits overlie shale and sandstone bedrock.

The typical geologic section along the dam axis as inferred from drill logs of the initial subsurface and borrow investigation (Reference 7) is shown on Plate No. 5. The foundation soils are predominantly very dense sandy gravels with some silt and clay fines, with a bedrock outcrop just upstream of the left abutment.

Seepage was observed during the inspection at numerous downstream locations on the slope face, embankment toe, abutment contacts, and around the outlet structure. Plate 3A summarizes the locations of observed seepage. The highest elevation of seepage was within 4 feet of pool elevation, indicating very little loss of head. Quantifying and differentiating seepage as to embankment leakage or underflow is difficult without piezometric data, flow measurements, and flow net studies. However, embankment leakage appears substantial (Photos 5 and 6).

The pronounced seepage around the outlet structure is apparently the result of inadequate seepage control (Photo 10). The seeps in the downstream slope indicate the lack of proper internal drainage and possibly an ineffective cutoff. Big Sky O & M personnel report a toe drain was constructed but were unable to locate the outlet. If the toe drain materials indicated by the plans were used, there would be potential for clogging and restricted drainage. No records of material actually used for the toe drain were available, nor is there record of whether or not it was actually built. In any case, the downstream drainage is ineffective.

2.3.3 Stability

No records of stability analysis were available, and there is insufficient data on soil strengths and seepage conditions to assess dam stability. The numerous seeps indicate a high phreatic surface in the downstream embankment slope which adversely affects dam stability.

The loose sand, gravel, debris, and fill dumped over the right abutment contact area was marginally stable at the time of inspection. There is evidence that this fill had sloughed on previous occasion(s). With the observed seepage in this area, the likelihood of continued movement is great. Major sloughing of this material could result in blockage of the outlet channel.

The seismic response of the dam has not, to our knowledge, been evaluated. Since the probability of a major seismic event is high and there is significant seepage resulting in local sloughs, it is our conclusion that the embankment is only marginally stable under static conditions and may be unstable in an earthquake of Richter Magnitude of 6.5-7.5.

2.4 PROJECT OPERATIONS AND MAINTENANCE

The project owners do not have an operations and maintenance plan, however, owner personnel cross the dam almost daily.

2.4.1 Dam Maintenance Plan

Regular operations and maintenance inspections have not been made by the sponsors since the dam was completed. Maintenance needs are reportedly taken care of as the need arises.

2.4.2 Reservoir

There is no formal plan for reservoir operations. Normal pool levels are maintained at the uncontrolled principal spillway, crest elevation 7420.0 feet NGVD. Low level outlet gates are used infrequently, with the upstream gate in closed position during normal operations.

2.4.3 Warning Plan

There is no formal warning plan for use in the event of impending dam failure.

CHAPTER 3
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of engineering data and design drawings for the project in terms of Guidelines (Ref. 1) resulted in the following findings:

3.1.1 Size, Hazard Classification and Dam Safety Evaluation

The 52-foot high dam impounds about 225 acre-feet of water with the reservoir at dam crest. In accordance with inspection guidelines, (Ref. 1) Big Sky Dam is intermediate in size and based on our visual inspection and judgment, it has a high downstream hazard potential. The guidelines recommend that a dam with the above classification be capable of safely handling the PMF. The dam overtops during the PMF when approximately 19 percent of the estimated PMF volume enters the reservoir. The project can just control a flood having hydrograph ordinates of 10 percent of the PMF hydrograph ordinates developed for this study. Because the project is incapable of handling a flood having one-half the PMF ordinates without overtopping and causing the dam to fail, and significant seepage problems exist, Big Sky Dam does not conform to the recommended guidelines and is considered unsafe, non-emergency until recommended actions are completed.

3.1.2 Outlet/Principal Spillway

The outlet works and principal spillway are combined into a single structure. The low level outlet, principal spillway riser, gate control tower, and the outlet conduit could not be inspected during the site visit because of reservoir level and pipe discharge. The upstream sluice gate on the low level outlet was in closed position. A wire screen around the base of the trash rack was clogged with leaves and debris inhibiting flow through the trash rack. One gate stem guide was broken just below the hoist base and the stem was bent in an "S" shape. Gate stems are unprotected from weather. No attempt was made to operate gates during the inspection because of apparent operating problems. The principal spillway flows are uncontrolled into the discharge conduit. Since the conduit passes through the earthen embankment, it would be desirable to have emergency closure capability at the riser in the event unforeseen problems develop with the conduit. Visible concrete appeared to be in good condition, with no serious cracks, structure settlement or misalignment. Some spalling of concrete surfaces was noted at the inside of control tower. The impact energy dissipator appeared in good condition, however, some erosion of earth materials is taking place around the ends and behind wingwalls.

3.1.3 Emergency Spillway

The excavated emergency spillway passes through a 108-inch-diameter corrugated metal pipe culvert on the left abutment. At the time of inspection, shoring and bracing possibly placed during construction was still in place on the inside of the pipe. Since these timbers and planks would severely obstruct flows, the inspection team immediately notified the Montana Department of Natural Resources and Conservation, who in turn notified the owners to remove the material. An additional site visit 30 days later verified that the shoring and bracing has subsequently been removed.

A sewer pipe and a water pipe are buried in the dam crest parallel to the axis of the dam and pierce the 108-inch-diameter CMP culvert. These pipes could obstruct flows by lodging large sized woody debris that may enter the culvert. A log boom should be located and anchored just upstream from the excavated emergency spillway crest to prevent floating debris from entering the exit channel.

The exit channel immediately downstream from the 108-inch-diameter culvert has a steep gradient approaching 10%. The sides and bottom of the excavated channel are composed of materials that are highly susceptible to erosion. Prolonged flood flows could undermine the culvert outlet and could possibly cause a breach of the left abutment of the dam. The emergency spillway is in need of immediate attention and modification to ensure safe passage of anticipated flood flows.

3.1.4 Reservoir Storage and Spillway Discharge

The reservoir has a surface area of about 9.8 acres and a storage of 113 acre-feet at principal spillway crest elevation 7420.0 feet NGVD. Approximately 112 acre-feet of surcharge storage is available between the principal spillway crest and dam crest elevation 7429.0 feet NGVD. The discharge capacity of the uncontrolled principal spillway, with the reservoir at dam crest elevation 7429.0 feet NGVD is approximately 416 c.f.s. The combined capacity of the two spillways is 1330 c.f.s. with the reservoir at the dam crest. The low level outlet has a capacity of approximately 200 c.f.s. with the reservoir at principal spillway crest elevation 7420.0 feet NGVD.

3.1.5 Dam Embankment

The embankment material is apparently an on-site sand-gravel mixture with varying amounts of silt and clay. The apparent intent was to blend these materials to form a homogeneous cross section with a core trench extending into dense sediments or bedrock. A toe drain of graded granular material was shown on the plans, but could not be confirmed in the field. Foundation materials consist of very dense sand-gravel or claystone shale and sandstone bedrock. Settlements have consequently been minimal.

Erosion of the upstream slope is minimal. Numerous seeps on the downstream slope face indicate a very high phreatic surface probably due to ineffective internal drainage and/or preferential seepage paths. This suggest that a homogeneous embankment may not have been achieved in construction. There is a large seep adjacent to the outlet structure, possibly the result of inadequate cutoff around the structure, and there is seepage at the abutment contacts. The potential for progressively increased seepage with attendent potential for increased erosion and sloughing is high. The presence of the water and sewer lines within the embankment is considered very undesirable. This is because of possible damage to the dam should a leak occur in one of these lines, especially the pressurized water line.

3.1.6 Stability

Stability of the downstream slope under steady-state seepage conditions does not conform with inspection criteria for stability (Ref. 1). Major earthquake loading under such conditions may fail the embankment. The loose, non-engineered fill dumped at the right or south abutment has

sloughed and continued movement of this dumped fill is likely unless corrective measures are taken.

3.1.7 Operations and Maintenance

Normal pool elevation is maintained at the uncontrolled principal spillway crest when inflows exceed seepage & evaporation losses. The low level outlet gate remains in a closed position and is rarely opened or tested. No formal operations plan for the reservoir exists. Maintenance is performed by Big Sky O & M personnel as required. There is no formal warning plan for use in the event of impending dam failure.

3.2 RECOMMENDATIONS

Due to storage between normal pool and dam crest the present project provides a small degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety, if feasible, without decreasing this existing flood protection.

1. Immediately develop, implement and periodically test an emergency warning plan for use in the event of impending dam overtopping or dam distress.

2. Inspect the control tower, gates, principal spillway, low level outlet and principal spillway conduit, and repair as required. Provide emergency closure capability of the principal spillway conduit at the riser.

3. Repair gate stem guide and lift stem. Test gates throughout their full range of operation at least twice a year.

4. Repair eroded areas around and behind the impact basin wingwalls.

5. Provide a barrier around the principal spillway trash rack to prevent floating debris from lodging against the trash rack.

6. Provide a log boom at entrance to emergency spillway.

7. Have a qualified, experienced geotechnical engineer immediately install piezometers and monitor the downstream slope, toe and abutments for any changes in seepage conditions, and to establish the phreatic surface for use in stability studies. Evaluate seepage and determine necessary measures to provide seepage control. Construct interim seepage control measures if needed, and incorporate final measures into stability enhancement measures described below.

The above recommendations will not make the dam safe, but will reduce risk to life while the following recommended actions are being taken.

8. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and the required spillway capacity to provide for safe passage of the recommended spillway design flood. Modify the project as studies indicate.

9. Conduct and place on file, a stability analysis of the dam embankment. This analysis should be performed by a qualified geotechnical engineer and be based on: static and seismic loading conditions; in situ strength properties of the embankment, foundation, and abutment materials; and actual phreatic surface conditions. Establish the material strength properties by drilling and sampling with laboratory testing as appropriate. Modify the project as studies indicate.

10. Provide for inspection by qualified engineers at 1 year intervals for the first 2 years following modification and at intervals not to exceed 5 years thereafter.

11. Develop and implement a periodic operations and maintenance plan for the project.

12. Remove sewer and water lines from the emergency spillway. Consider routing these pipes away from the dam or protect the dam from erosion should the pipes fail.

13. Prior to performing engineering studies and remedial construction, coordinate the work with the State of Montana Department of Natural Resources and Conservation to insure compliance with all pertinent laws and regulations.

REFERENCES

1. U.S. Army Corps of Engineers, Office the Chief of Engineers Report to the U.S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspection of Dams," Washington, D.C.; Department of the Army, May 1975.

2. William C. Alden, Physiography and Glacial Geology of Western Montana and Adjacent Areas, Geological Survey Paper 231, 1953.

3. G. J. Wicks, The Framework Report, Montana Department of Natural Resources and Conservation, Water Resources Division, Vol. 1, 1976.

4. U.S. Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package Dam Safety Investigations, Davis CA, Sept. 1978.

5. U.S. Weather Bureau, Hydrometerological Report No. 43 - Probable Maximum Precipitation Northwest United States, November, 1966, Washington D.C.

6. U.S. Soil Conservation Service, National Engineering Handbook, Section 4, Hydrology, 1972.

7. Northern Testing Laboratories, Report on Subsurface Soil and Embankment Borrow Material Investigations For Mountain Village Damsite, Big Sky Montana, September, 1972.

8. National Weather Service, "Interim All Season Probable Maximum Precipitation Estimates, Missouri River Basin West of the 105th Meridan," January, 1980.

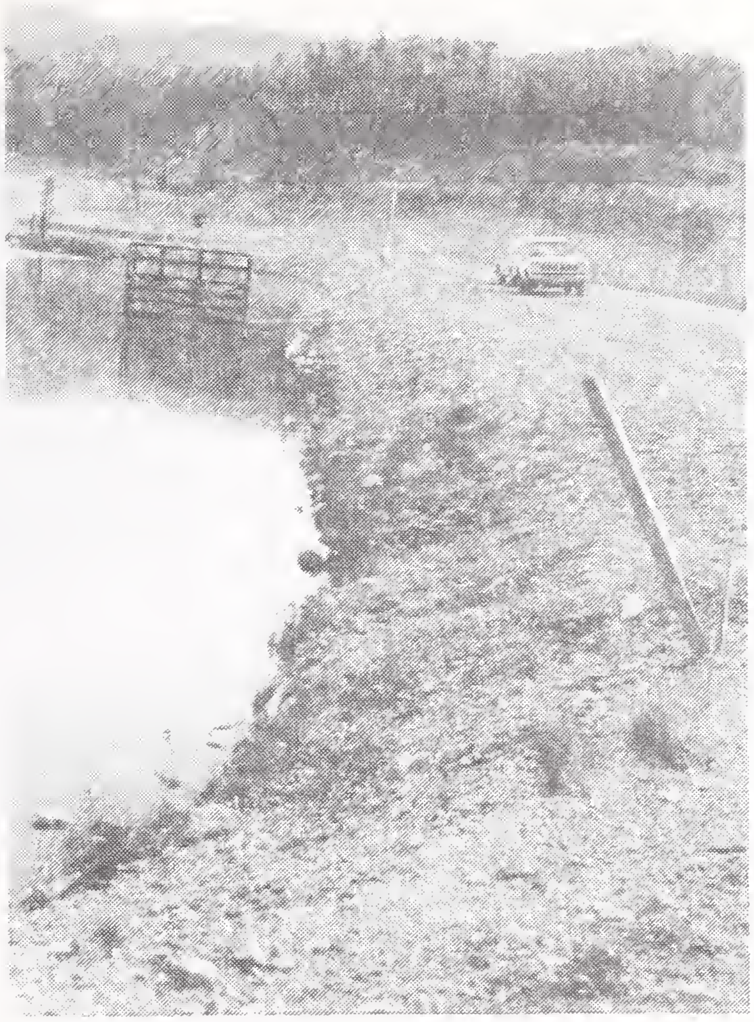


PHOTO 1 - Upstream Face

Note: Principal spillway tower & trashrack in reservoir

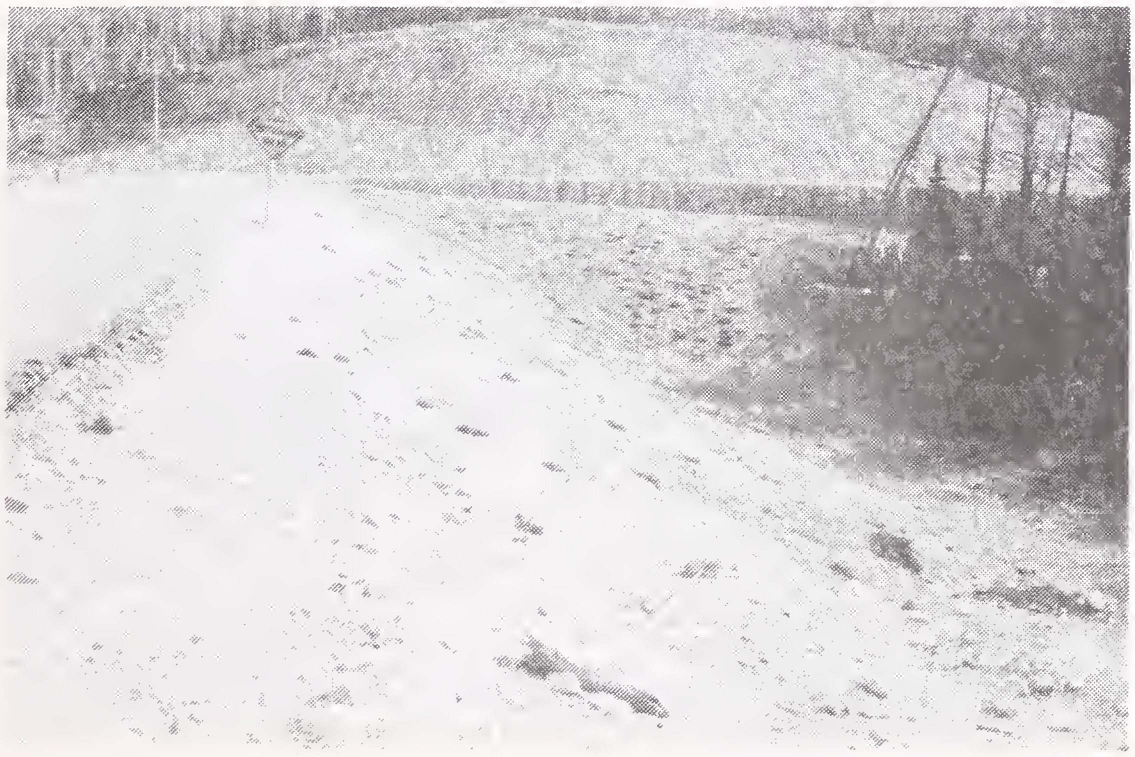


PHOTO 2 - Downstream Side of Left or North Abutment

Note: Dam crest roadway at left, emergency spillway exit channel at top, center to right.

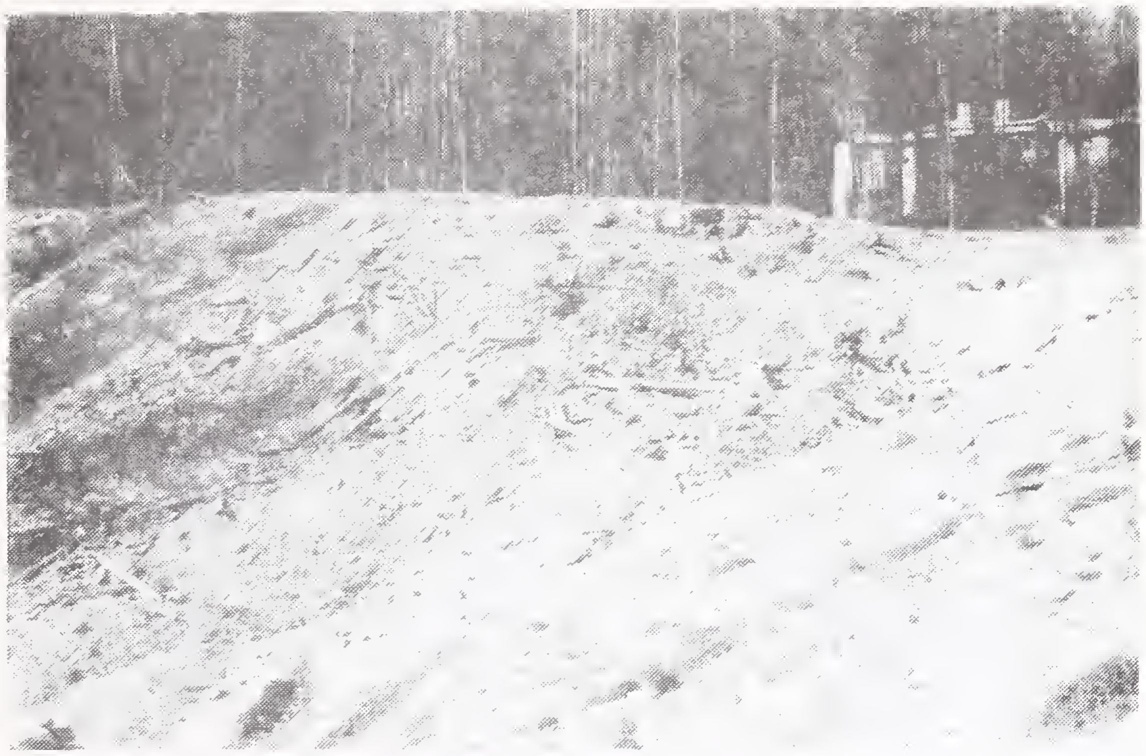


PHOTO 3 - Crest of Right or South Abutment

Note: Loose fill & seepage areas

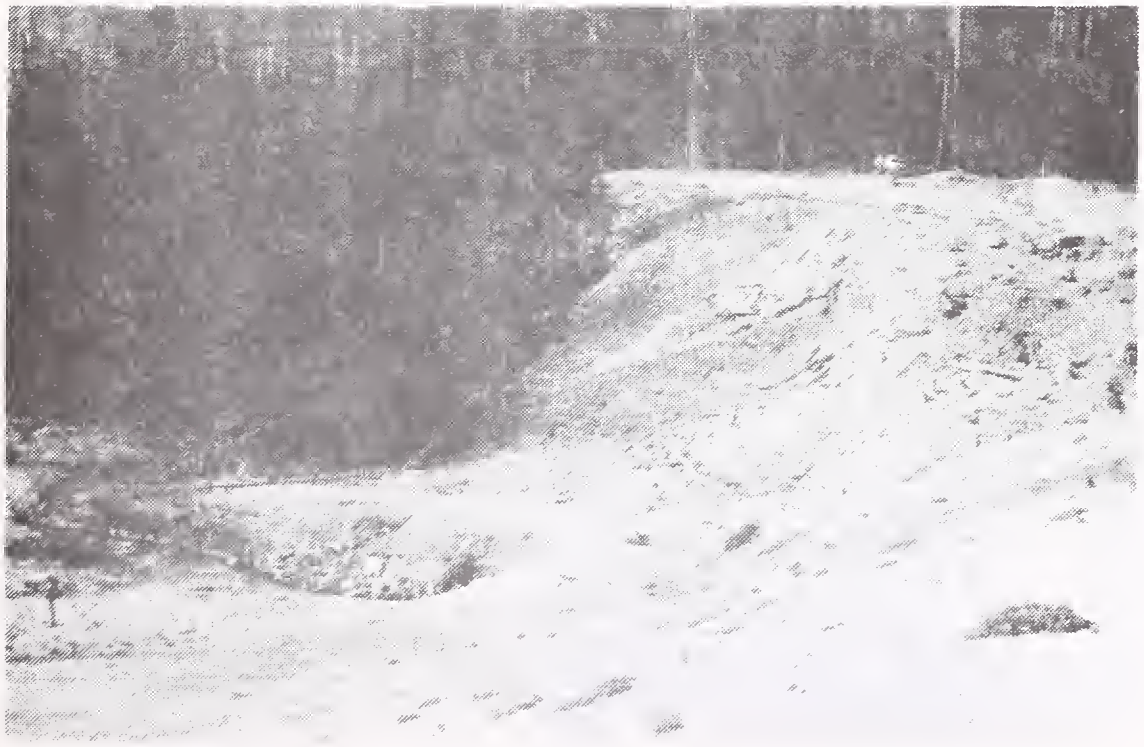


PHOTO 4 - Toe of Right or South Abutment

Note: Loose fill, also P.S. impact basin at bottom center.

PHOTO 5 - Seepage Area on Downstream Face

PHOTO 6 - Seepage Areas on Downstream Face

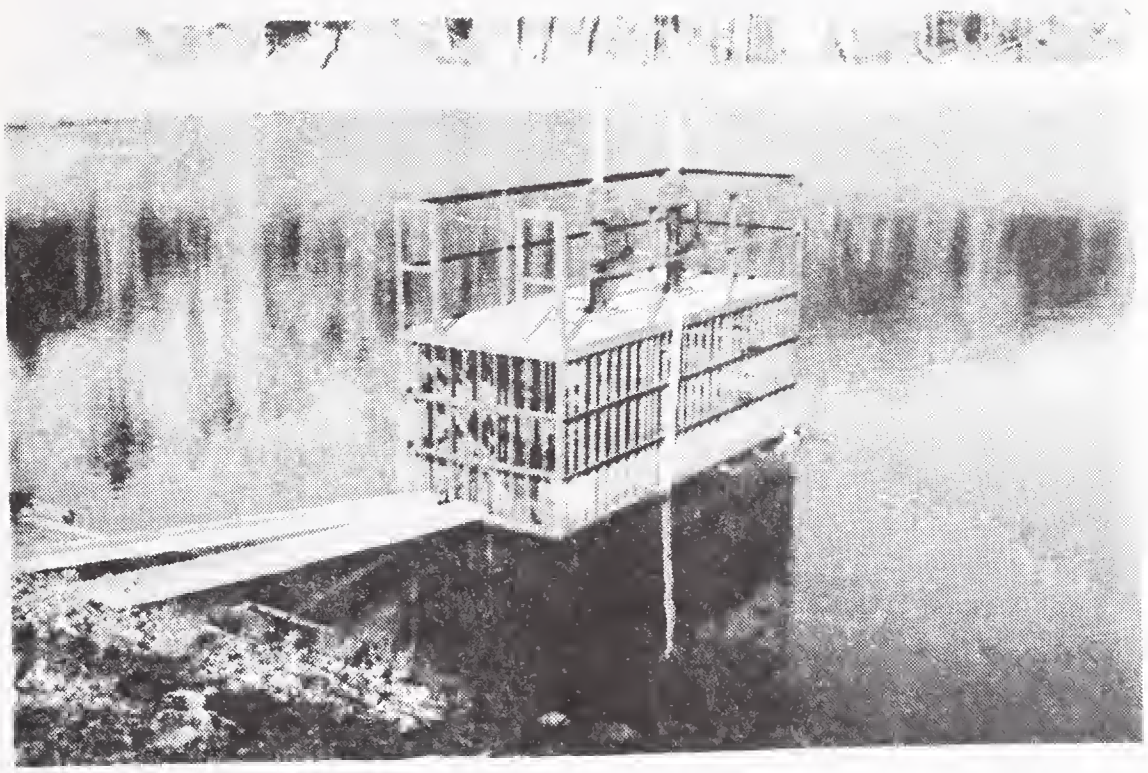


PHOTO 7 - Principal Spillway Tower, Trashrack & Gate Controls

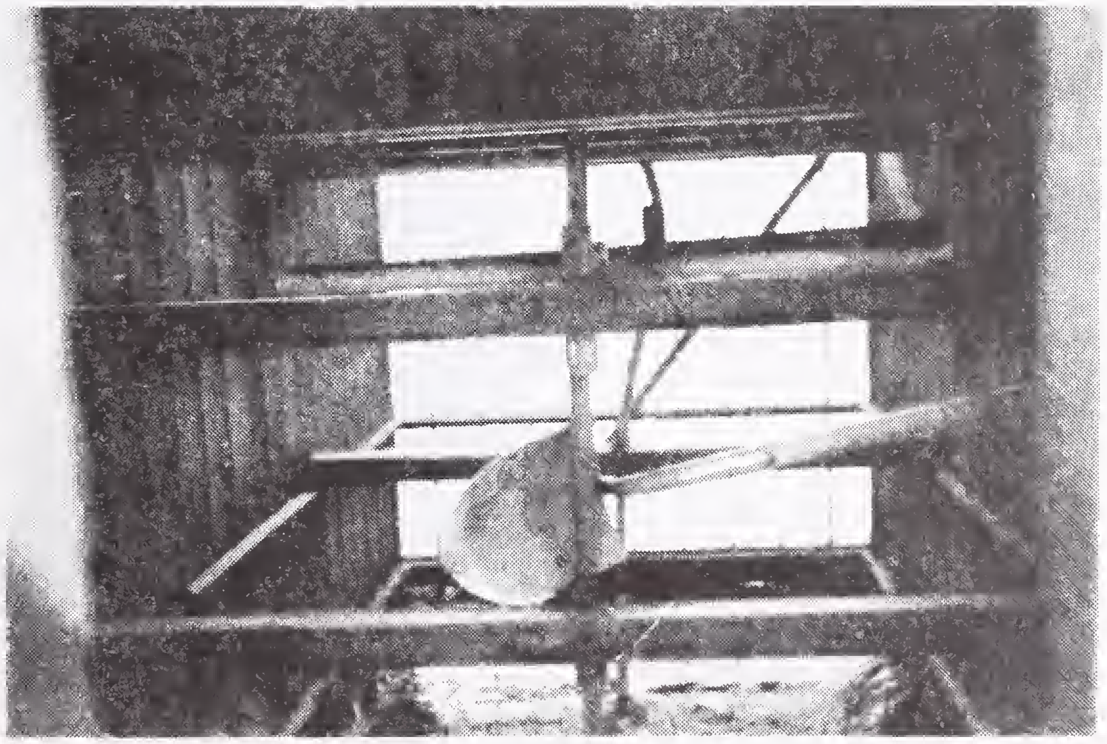


PHOTO 8 - Bent 1 inch diameter Gate Control Bar

PHOTO 9 - Impact Basin

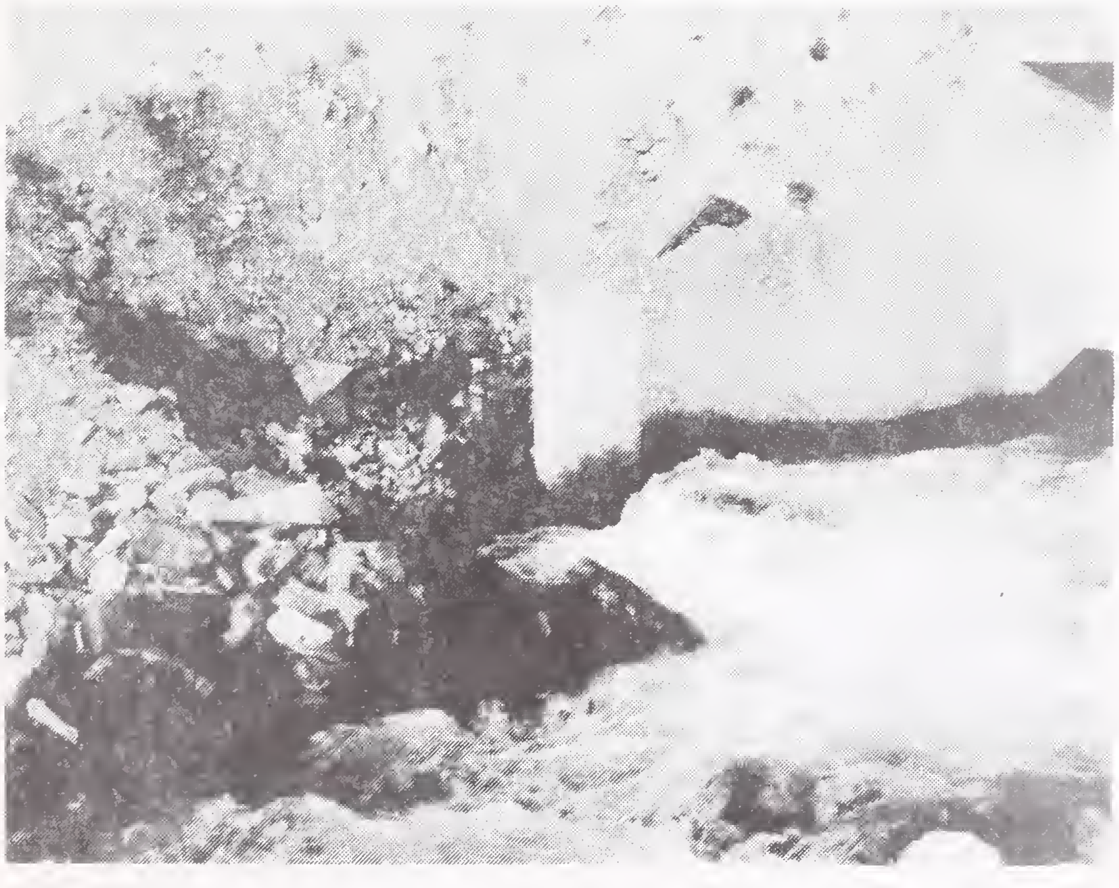


PHOTO 10 - South Corner of Impact Basin
Note: Sloughing and seepage area

PHOTO 11 - Dam Crest Looking Towards North or Left Embankment
Note: Emergency spillway crest on far shore

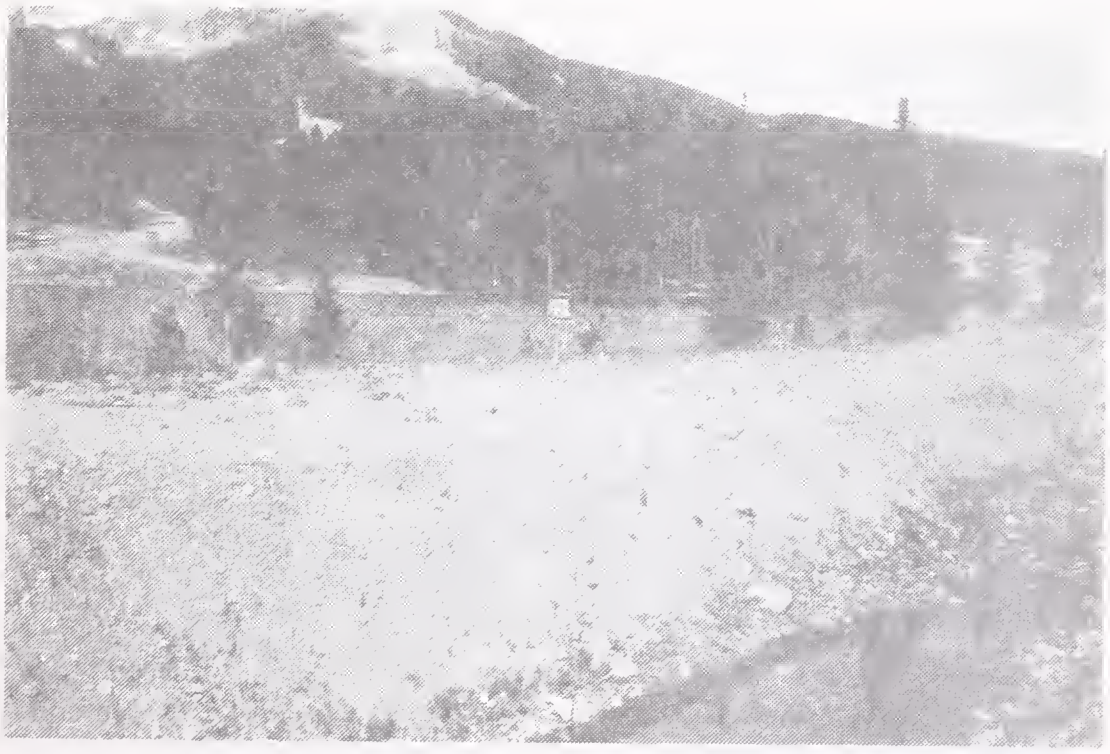


PHOTO 12 - Emergency Spillway Crest Looking Southwest
Note: Water in E.S. exit channel due to seepage

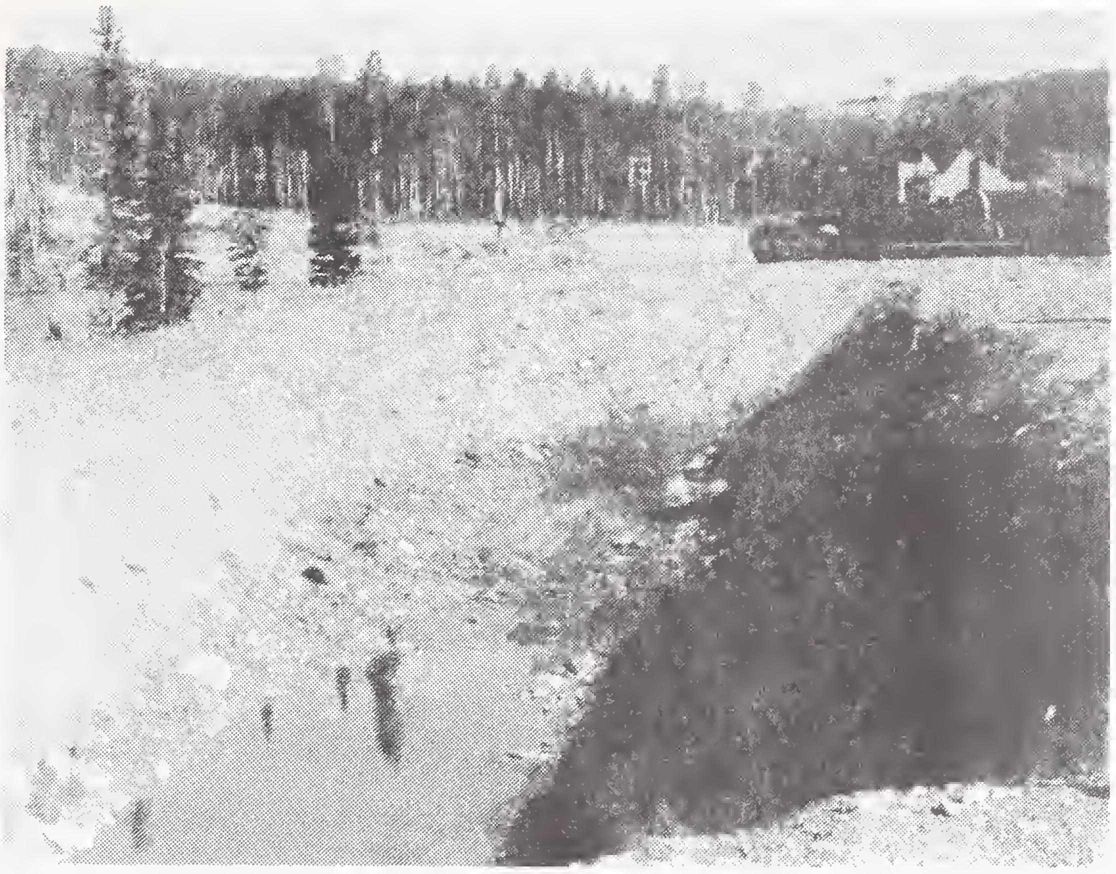


PHOTO 13 - Emergency Spillway Exit Channel
Looking West or Upstream From Top of Dam

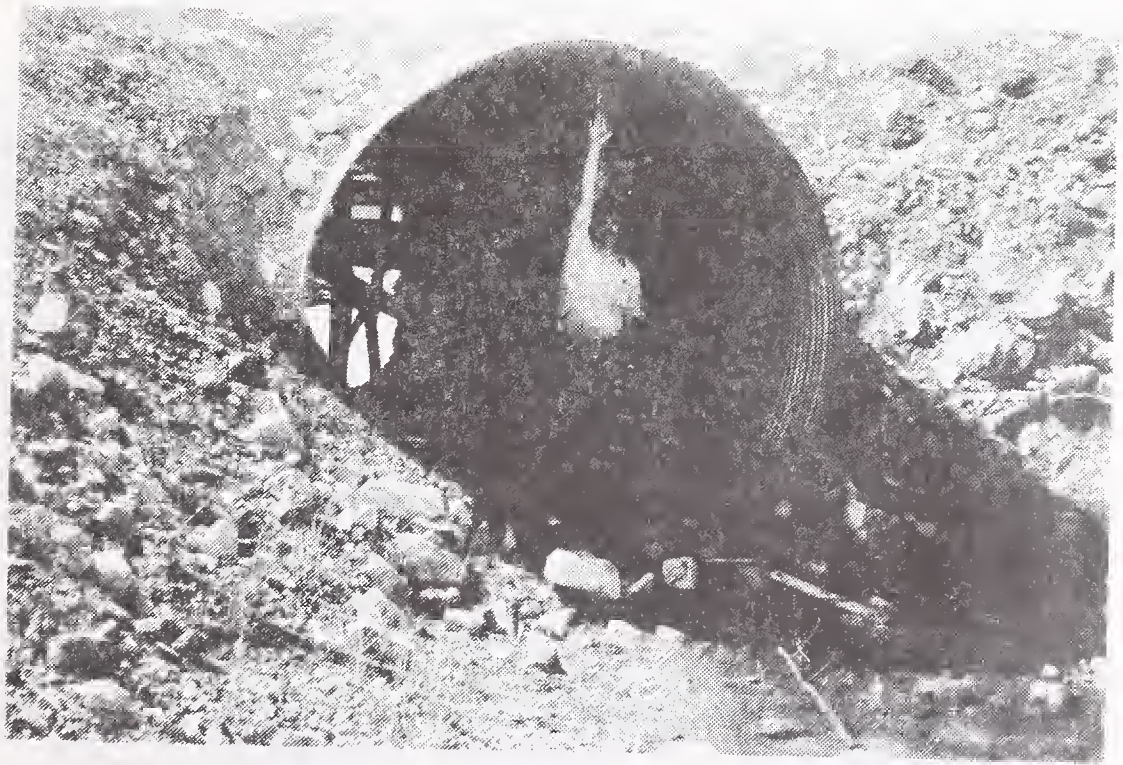
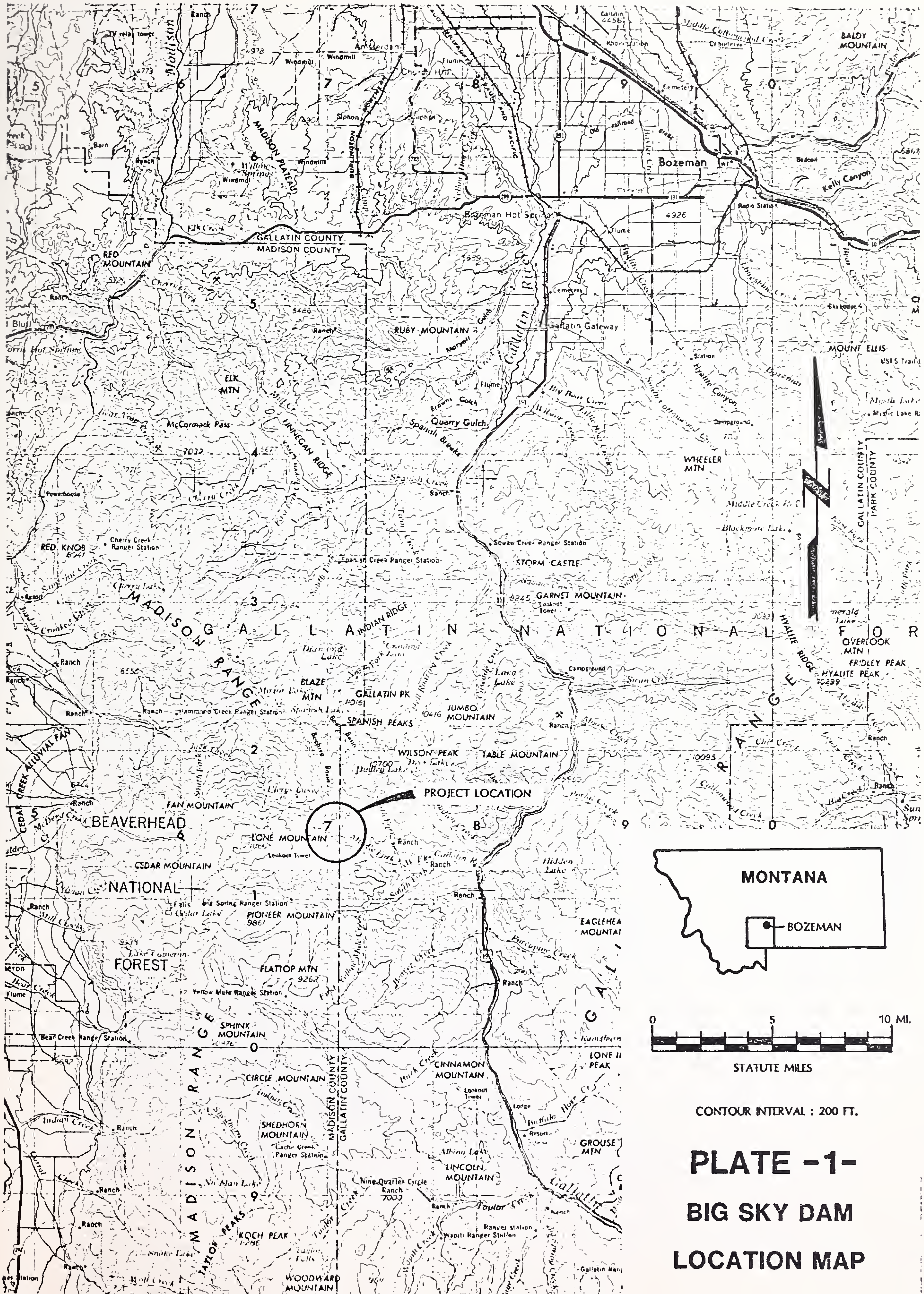


PHOTO 14 - Entrance to 108 inch diameter CMP
Note: Sloughing, bracing & service mains

PHOTO 15 - Inside 108 inch diameter CMP in Emergency Spillway Exit Channel

Note: Bracing and water and sewer mains

PHOTO 16 - Emergency Spillway Exit Channel Looking Upstream Towards Dam



CONTOUR INTERVAL : 200 FT.

PLATE -1-

BIG SKY DAM

LOCATION MAP

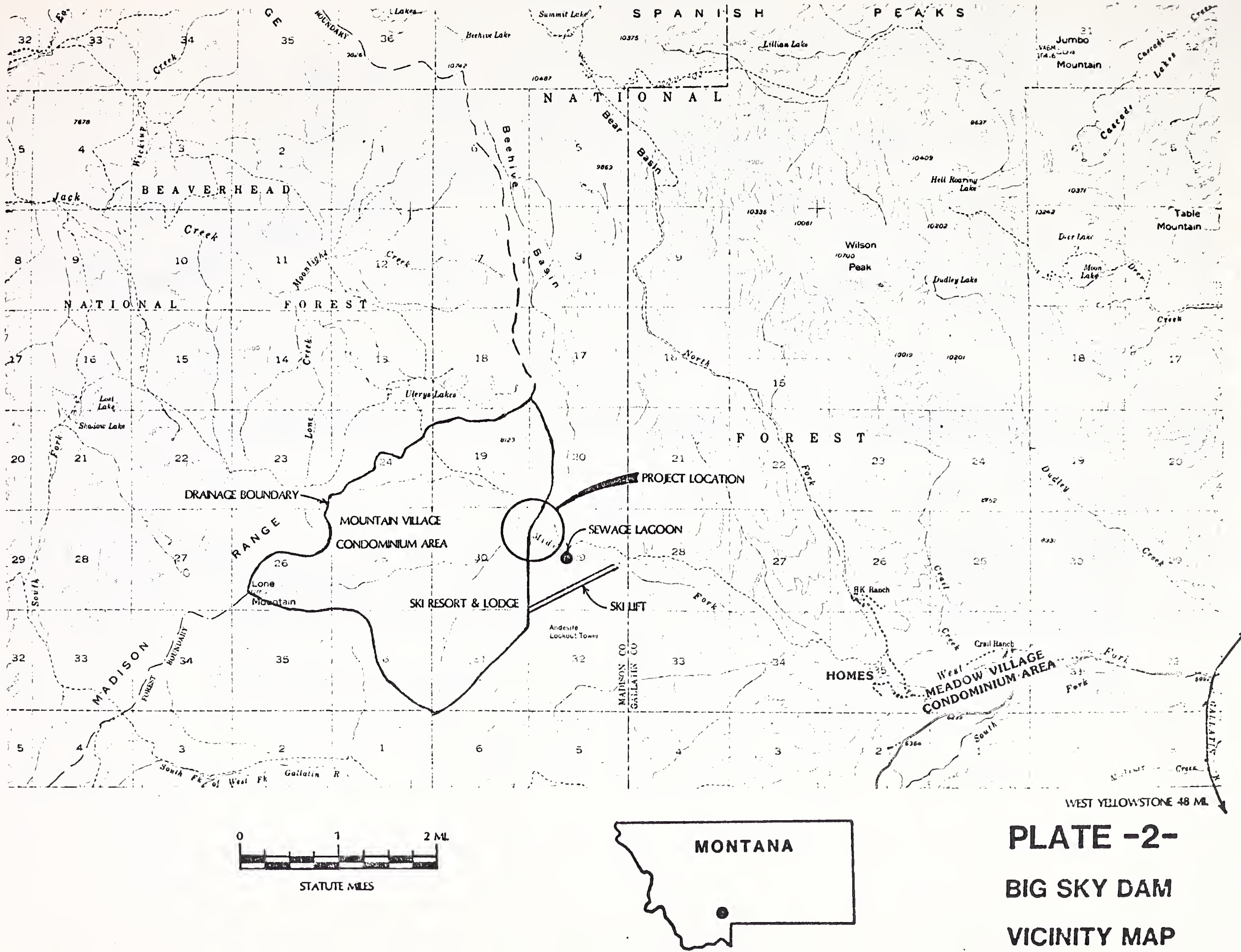


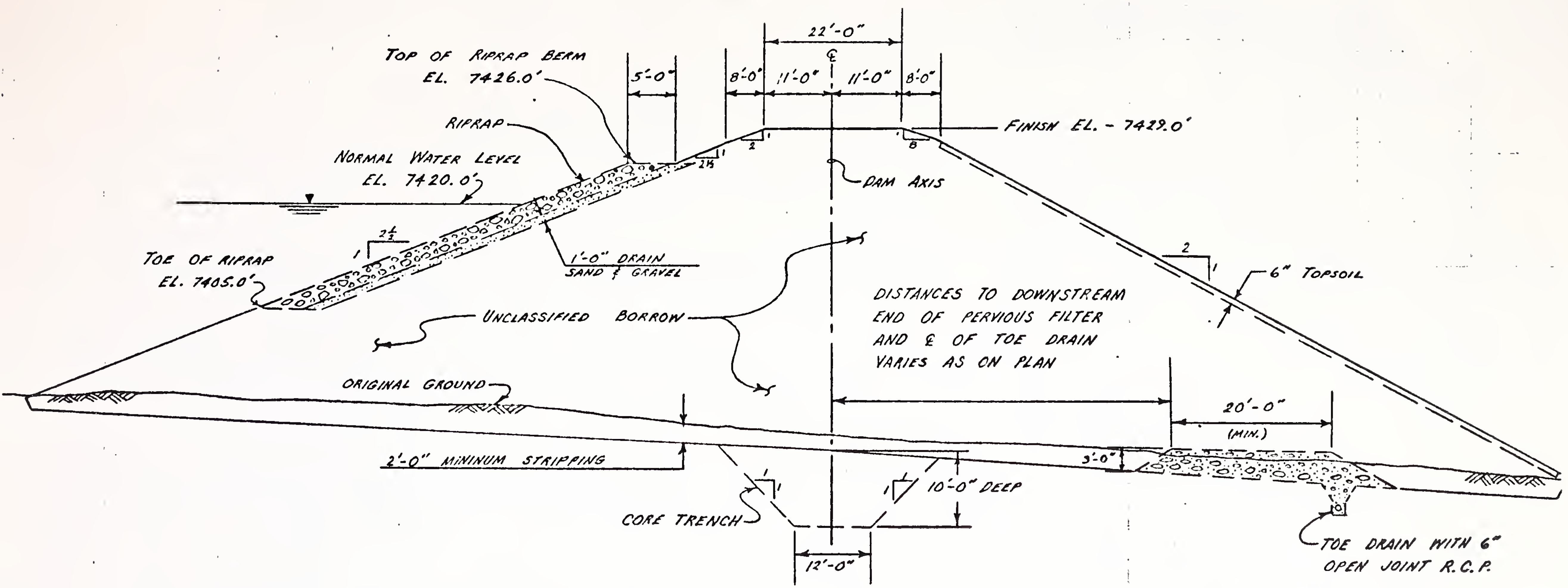
PLATE -2-

BIG SKY DAM

VICINITY MAP

TYPICAL SECTION

NO SCALE



NOTES:

1. ALL INFORMATION ON THIS PLATE HAS BEEN REPRODUCED FROM MORRISON-MAIERLE, INC. DRAWING 1235-06-01, SHEET 2.
2. DESIGN DETAILS NOT CONFIRMED BY FIELD INSPECTION OUTLINED IN DASHED LINES

PLATE -3-

BIG SKY DAM

DAM SECTION

TYPICAL SEEPAGE DISTRIBUTION ON DOWNSTREAM SLOPE FACE

SECTION AT STA. 2+45

SCALE: 1"=20'

NOTE:

▽ = SEEP LOCATION

TABLE LOCATING ADDITIONAL SEEPAGE

SEEPAGE ELEV.	OFFSET DISTANCE FROM SECTION AT STA. 2+45
7394.3	30' RT.
7395.0	6' LT.
7397.0	90' LT.
7397.8	80' LT
7398.7	22' LT.
7399.0	30' LT.
7399.0	50' LT.
7407.4	90' LT.
7414.0	20' RT.
7417.0	30' LT.

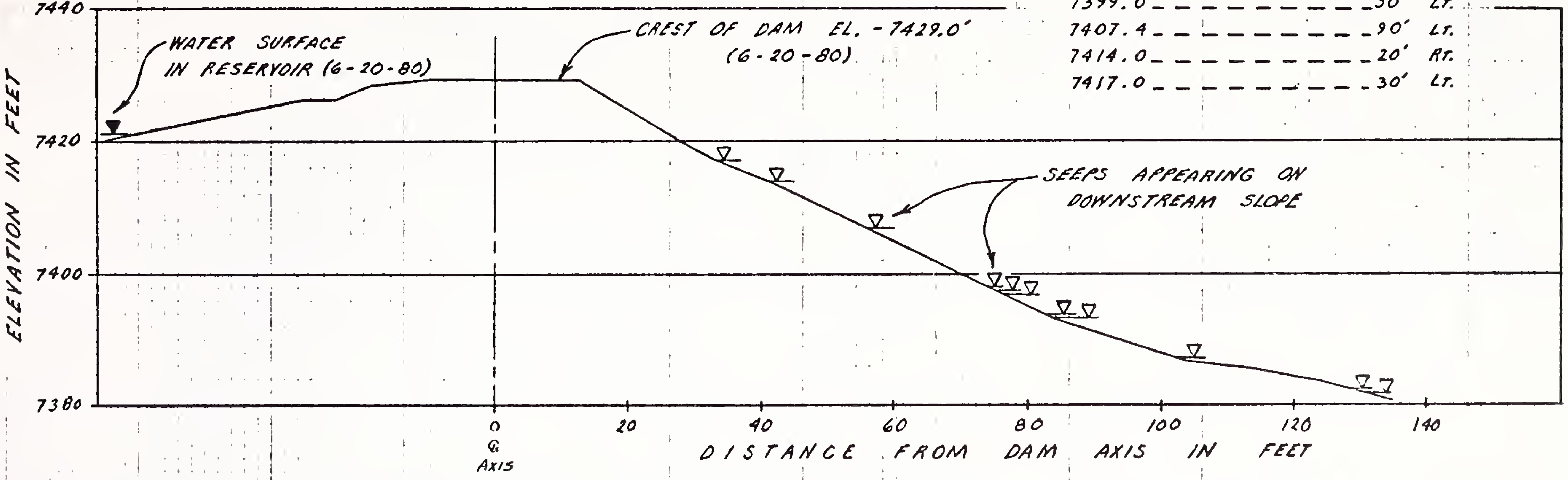

WATER SURFACE IN RESERVOIR (6-20-80)
CREST OF DAM EL. -7429.0' (6-20-80)
SEEPS APPEARING ON DOWNSTREAM SLOPE
7440
7420
7400
7380
ELEVATION IN FEET
0
℄ AXIS
20
40
60
80
100
120
140
DISTANCE FROM DAM AXIS IN FEET

PLATE -3A-

BIG SKY DAM

DAM SECTION W / SEEPS

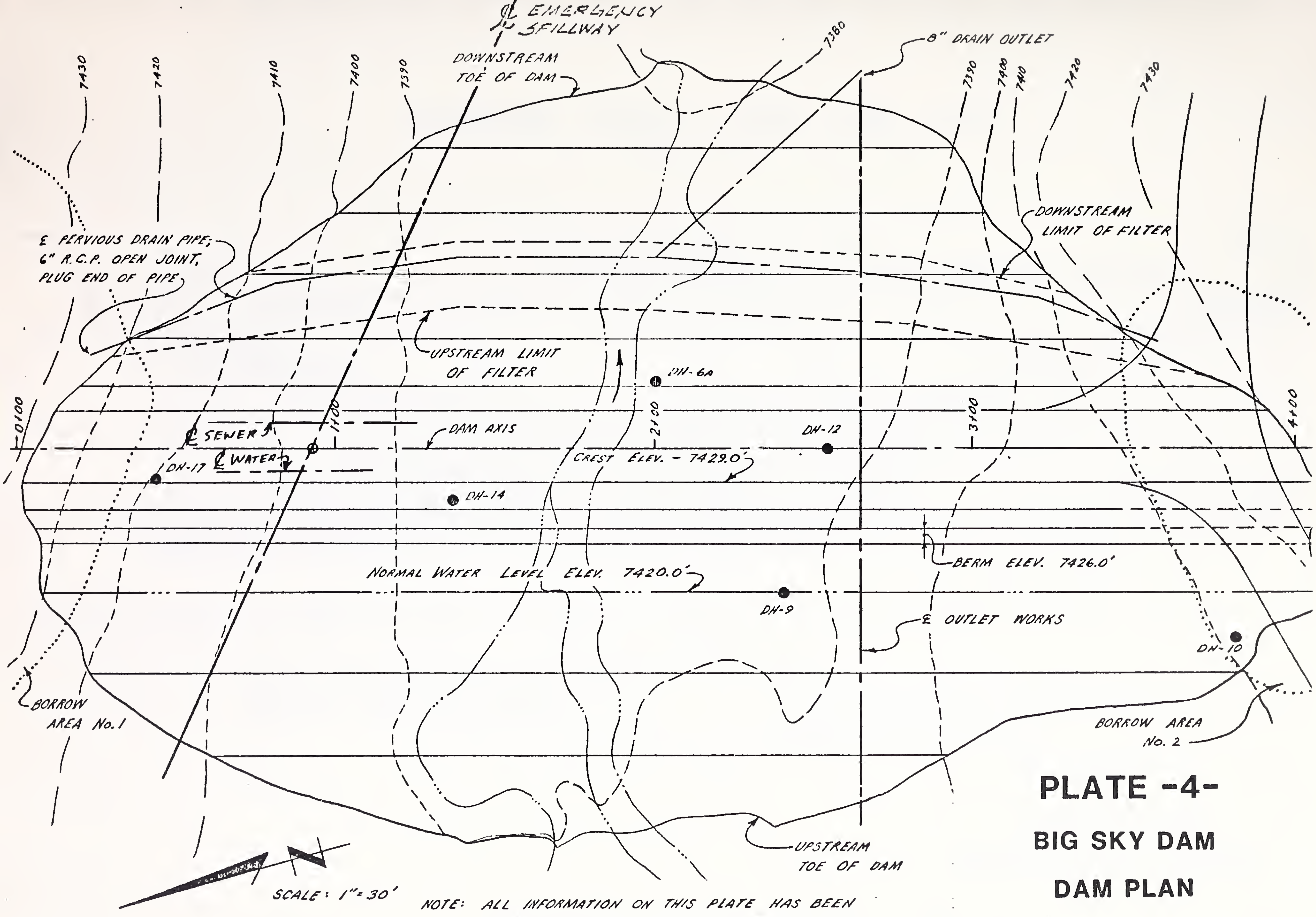


PLATE -4-

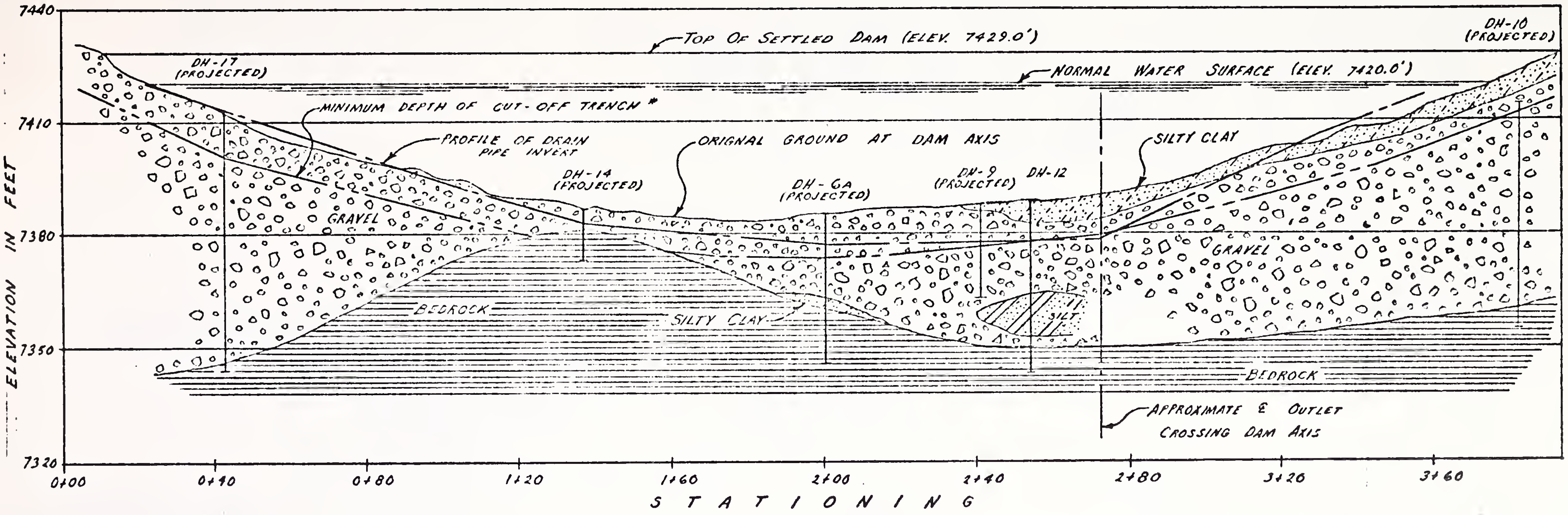
BIG SKY DAM

DAM PLAN

NOTE: ALL INFORMATION ON THIS PLATE HAS BEEN REPRODUCED FROM MORRISON-MAIERLE, INC. DRAWING 1235-06-01, SHEET 2

GENERALIZED PROFILE ALONG DAM AXIS

SCALE: 1" = 30'

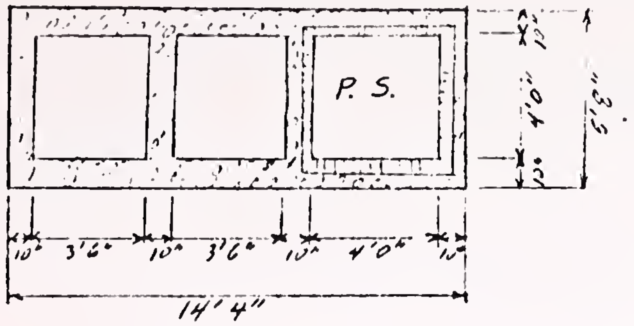


*CUT-OFF TRENCH EXCAVATED AND PARTIALLY BACKFILLED, EXACT LIMITS UNKNOWN

NOTE:
ALL INFORMATION ON THIS PLATE HAS BEEN REPRODUCED FROM MORRISON-MAIERLE, INC. DRAWING 1235-06-01, SHEET 2

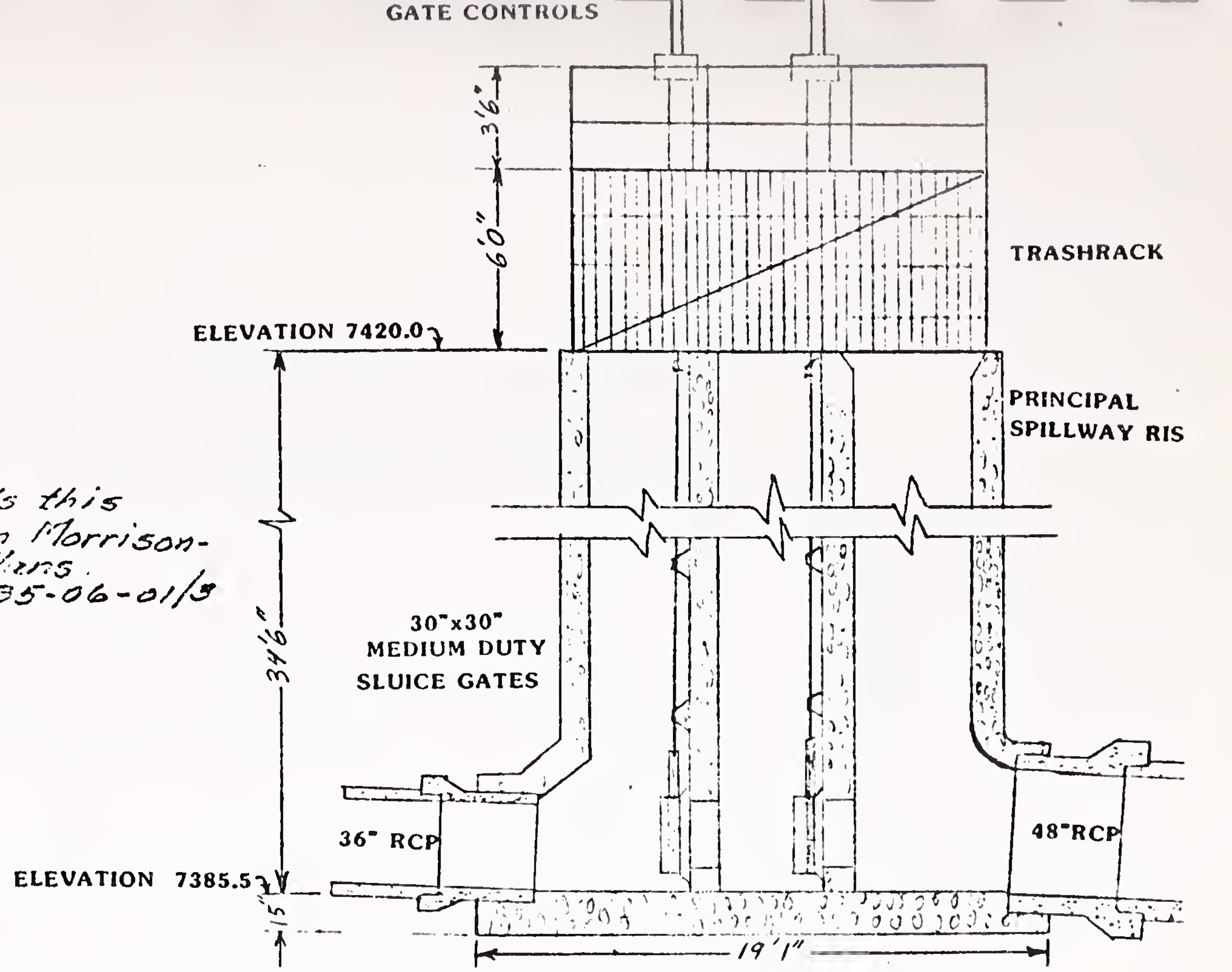
PLATE -5-

BIG SKY DAM
FOUNDATION PROFILE

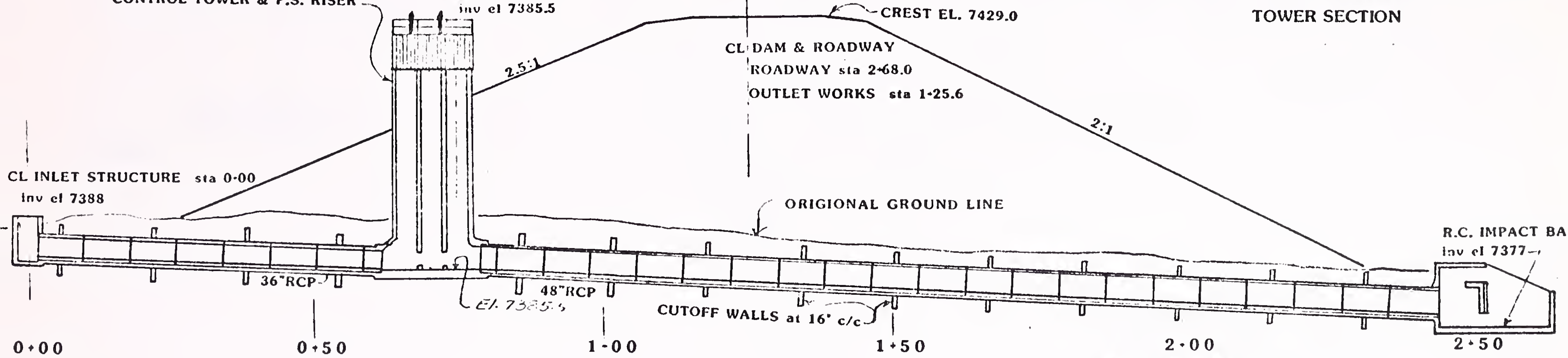


TOWER PLAN

NOTE: All details this page from Morrison-Maierle Plans. Sheet #1235-06-01/3



TOWER SECTION



PROFILE - PRINCIPAL SPILLWAY & OUTLET WORKS

PLATE -6-
BIG SKY DAM
OUTLET WORKS & PRINCIPAL SPILLWAY
SECTION & DETAILS

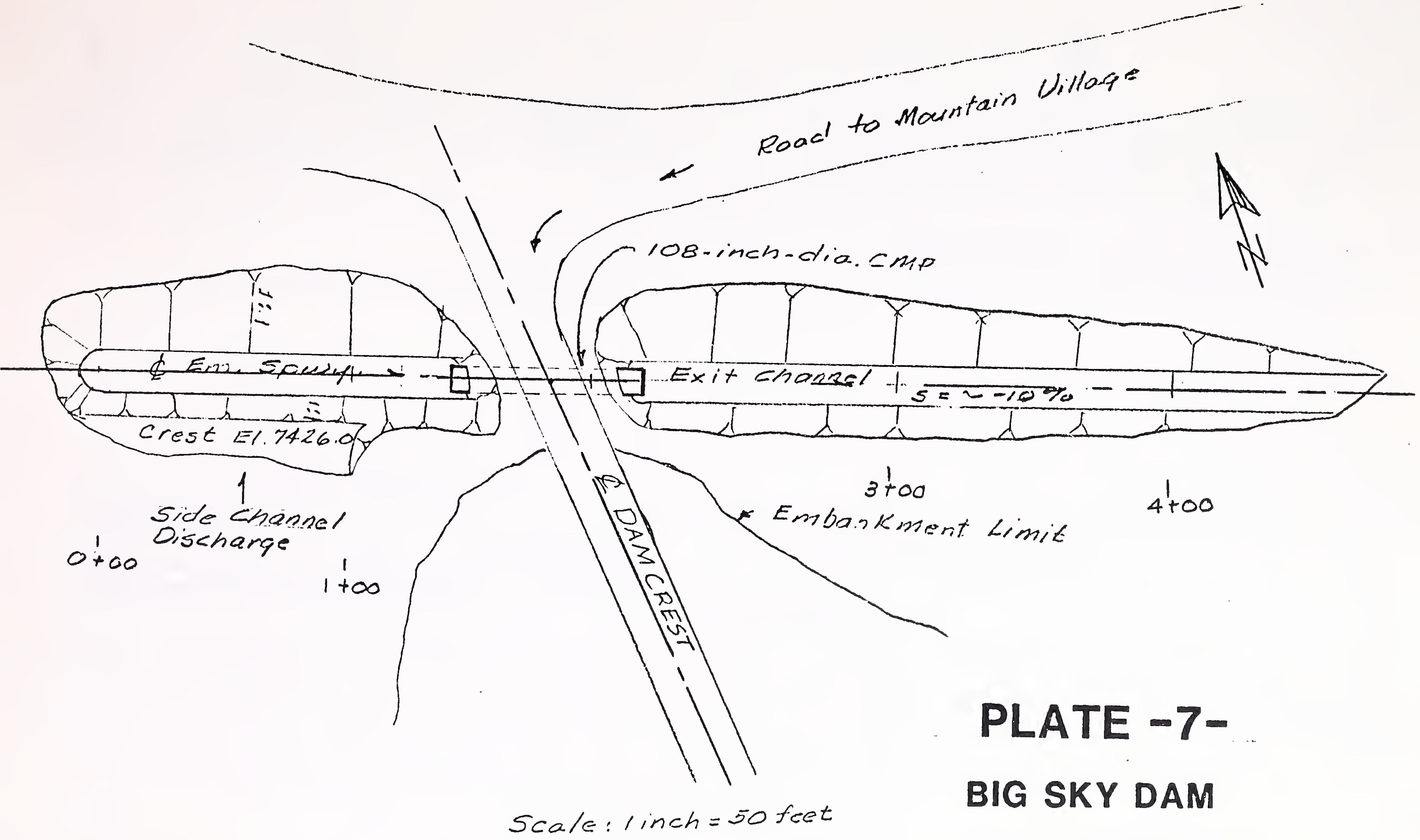
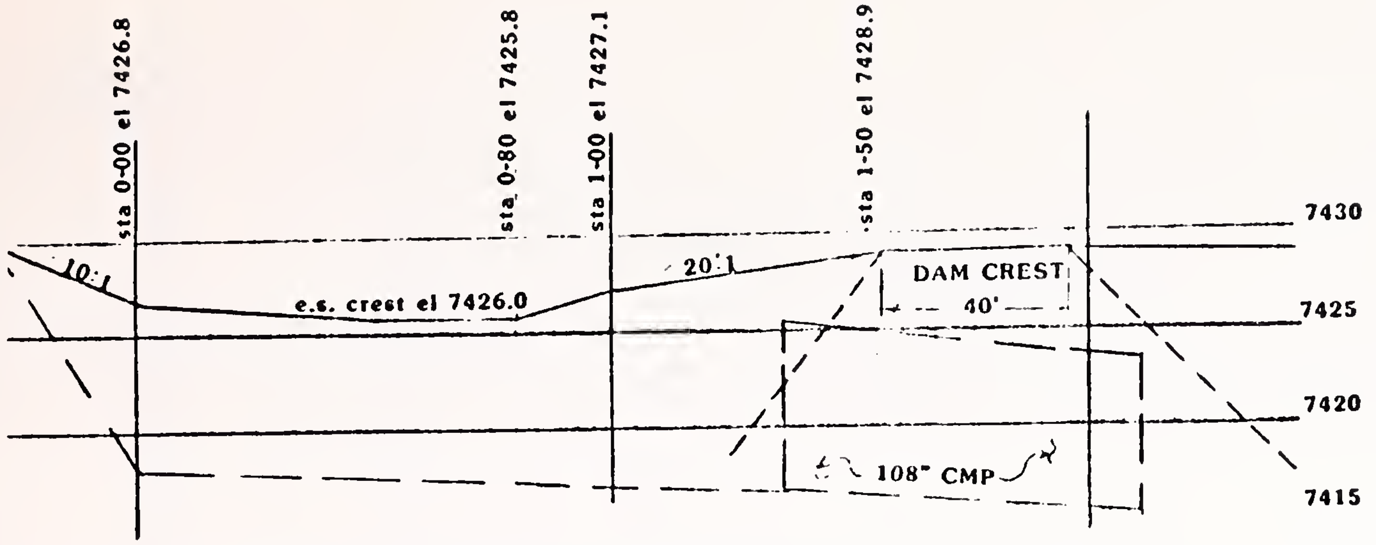


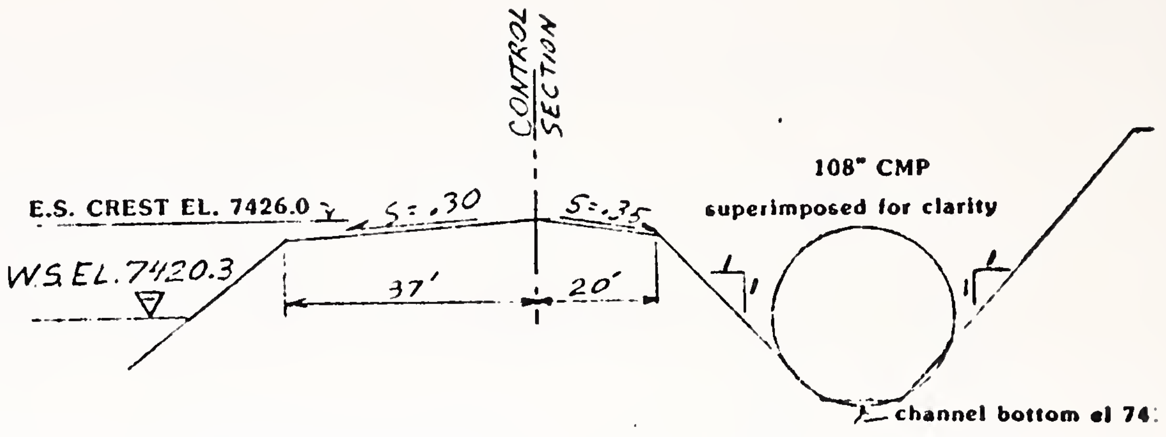
PLATE -7-

BIG SKY DAM

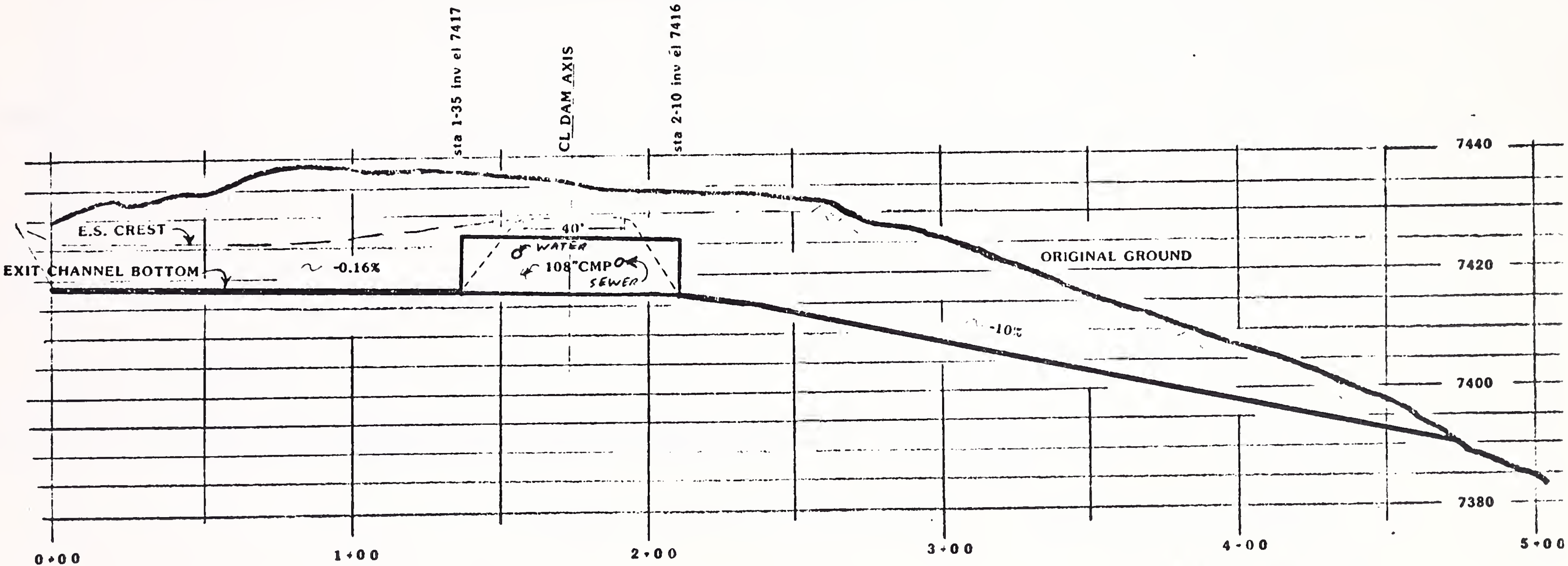
PLAN - EMERGENCY SPILLWAY



EMERGENCY SPILLWAY CREST SECTION AS SURVEYED 6/80



EMERGENCY SPILLWAY
CREST PROFILE & EXIT CHANNEL SECTION AS SURVEYED 6/80



EMERGENCY SPILLWAY EXIT CHANNEL PROFILE

PLATE -8-

BIG SKY DAM

EMERGENCY SPILLWAY

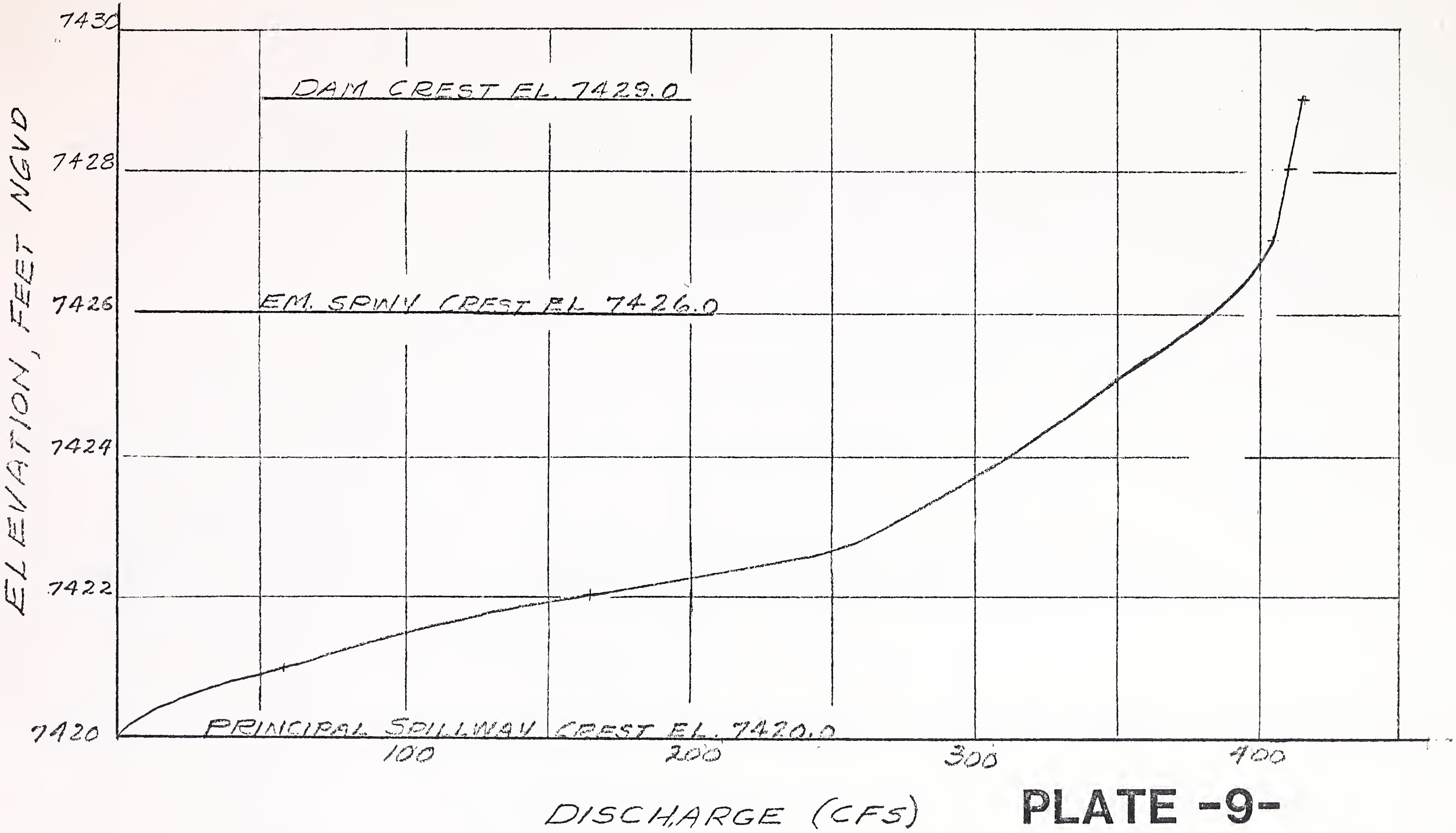


PLATE -9-

BIG SKY DAM

PRINCIPAL SPILLWAY RATING CURVE

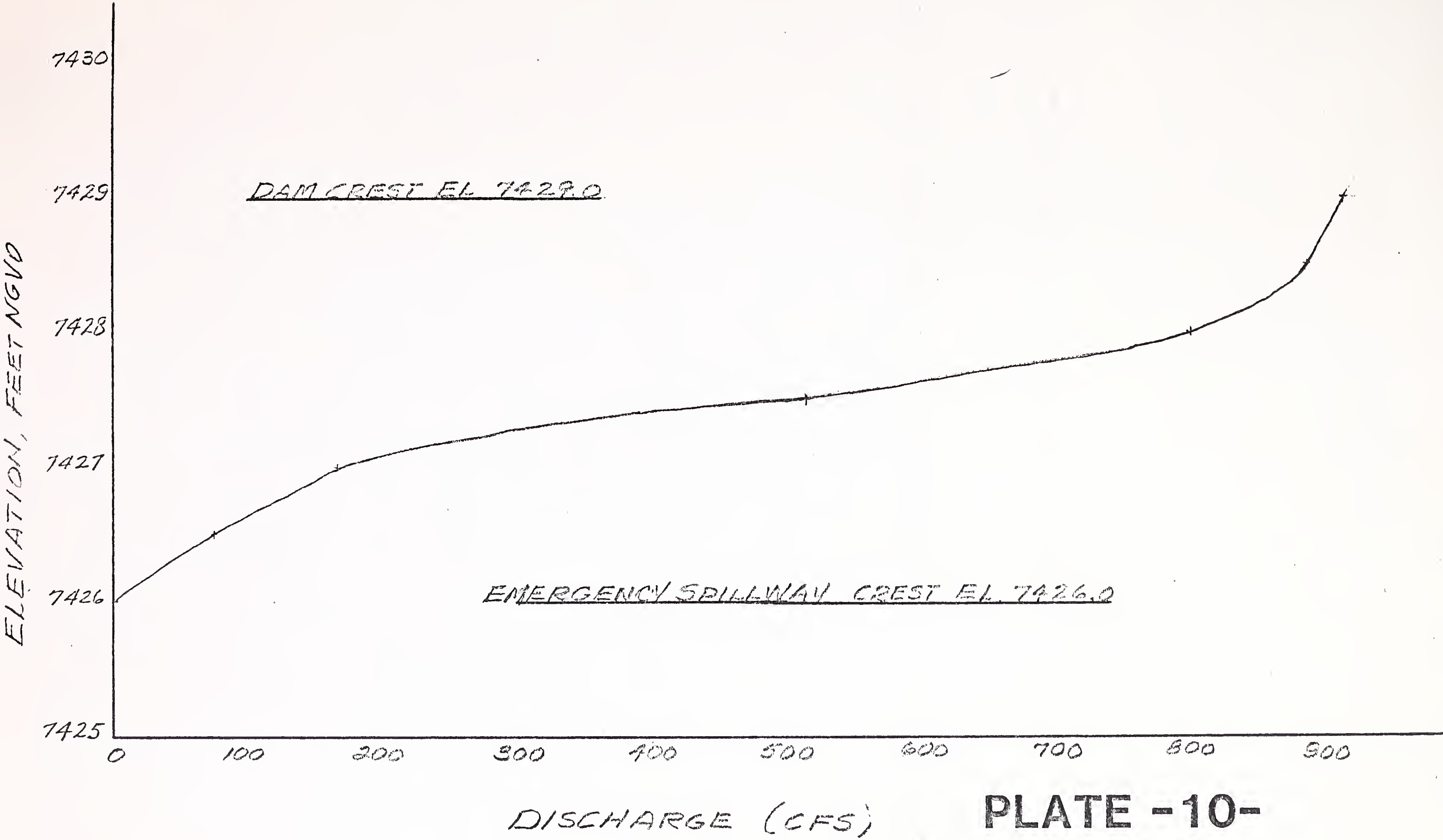


PLATE -10-

BIG SKY DAM

EMERGENCY SPILLWAY RATING CURVE

APPENDIX A

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE GOVERNOR
32 SOUTH EWING
STATE OF MONTANA
(406) 449-2872
HELENA, MONTANA 59601

June 26, 1980

Big Sky of Montana, Inc.
Mr. Terry Onslow, General Manager
P.O. Box 1
Big Sky, MT 59716

Dear Mr. Onslow:

On Friday, June 20, 1980 Big Sky Dam near the Mountain Village was inspected by a consulting engineer under contract with the Department of Natural Resources and Conservation. Following the inspection, our consulting engineer wrote us the enclosed letter addressing some conditions he observed at the dam. These conditions were brought to your attention by Mr. McDonald of our office on Tuesday, June 24, 1980. We feel that immediate action should be taken to help reduce the hazard created by these conditions. Failure of the dam could cause loss of life as well as extensive property damage.

The reservoir level should be immediately lowered about 20 feet, to help reduce the hazard, until repairs can be made to the emergency spillway outlet conduit, and the upstream gate stem on the principal spillway. The screen on the trash rack on the principal spillway should also be removed.

An engineer should be contacted to determine the hazard posed by the sanitary sewer line and the water line which runs through the dam. The question to be addressed is if the water and sewer lines were damaged, would they have an adverse effect on the safety of the dam. If the safety of the structure is affected then a better location should be found for the location of the lines. The lines should be located such that they do not obstruct flow through the emergency spillway conduit. These determinations should be made before the reservoir is refilled.

If you have any questions please contact us at 449-2864.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau

RB/AT/mb
cc: Ralph Morrison
Enclosure

CHRISTIAN, SPRING, SIELBACH & ASSOCIATES

CONSULTING ENGINEERING
SURVEYING
PHOTOGRAMMETRIC ENGINEERING

June 24, 1980

RECEIVED
JUN 24 1980
MONT. DEPT. OF NATURAL
RESOURCES & CONSERVATION

Richard L. Bondy, Chief
Engineering Bureau
Montana Department of Natural
Resources and Conservation
32 S. Ewing
Helena, MT 59601

RE: Field Inspection Big Sky Dam

Dear Mr. Bondy:

Our firm along with Northern Testing Labs., personnel and a representative of your department, Art Taylor made a field inspection of Big Sky Dam on Friday, June 20, 1980. Mr. Ray Tout, Maintenance Supervisor for Big Sky was also present for part of the inspection.

As discussed with you on the telephone yesterday a.m. (June 23, 1980), the following conditions were observed which we felt should be immediately brought to your attention:

1. A large corregated metal pipe in the emergency spillway which serves as a crossing for the road on the top of dam, is severely obstructed with wood post bracing and struts inside the pipe.

2. The trash rack and gate hoist base at entrance to the principal pipe spillway had a wire mesh screen placed around the base of the trash rack at the spillway crest. The screen was plugged with leaves and debris, and was severely restricting flows in the principal spillway.

3. A field fabricated stem guide on the gate stem controlling the upstream gate in the principal spillway had broken loose. The gate stem was badly bent making the gate hoist inoperative. The upstream gate controls lake levels and was in a closed position.

It is our feeling that the obstruction in spillways and the inoperative gate would pose a serious threat to dam safety in the event of an unusual storm event causing flooding at the site.

Sincerely,

CHRISTIAN, SPRING, SIELBACH & ASSOC.

Bob

Bob B. Gemmell
Principal Engineer
Water Resources

BBG/srh
cc: Ralph Morrison

Boyne USA
RESORTS
BIG SKY · BOYNE MOUNTAIN · BOYNE HIGHLANDS

February 20, 1981

U.S. Army Corp of Engineers
Seattle District Office
Seattle, Washington 98104

RE: Big Sky Dam Inspection

Dear Sir:

We wish to thank the Corp of Engineers for initiating the recent inspection of our dam at Mountain Village, Big Sky of Montana.

This is to inform you that the recommendations presented by Christian, Spring, Sielbach & Associates, and the Montana Department of Natural Resources, will be complied with as soon as possible. The heavy snow and ice in the area will prevent us from complying with the recommendations immediately. We will proceed as soon as conditions permit.

Sincerely,

Ray Tout

Ray Tout
Engineering Dept.
Big Sky of Montana, Inc.

cc: Robert J. Fritz
Everett Kircher

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

TED SCHWINDEN, GOVERNOR
32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872 ADMINISTRATOR
(406) 449-3962 WATER RIGHTS BUREAU
(406) 449-2872 WATER SCIENCES BUREAU
(406) 449-2864 ENGINEERING BUREAU
(406) 449-2872 WATER PLANNING BUREAU
HELENA, MONTANA 59620

February 27, 1981

Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Attn: Ralph Morrison

Re: Christian, Spring, Sielbach & Associates Dam Safety Inspection Report on Big Sky Dam (MT-1395)

Dear Ralph:

We have reviewed the above referenced final draft report. We concur with the findings and recommendations and find that it satisfies the criteria of the Phase I report.

Minor editorial comments have been discussed with your staff, and we understand these will be incorporated in the final report.

Thank you for the opportunity to review and comment on the final draft report on Big Sky Dam.

Sincerely,

Richard L Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB:AT:lj

"AN EQUAL OPPORTUNITY EMPLOYER"